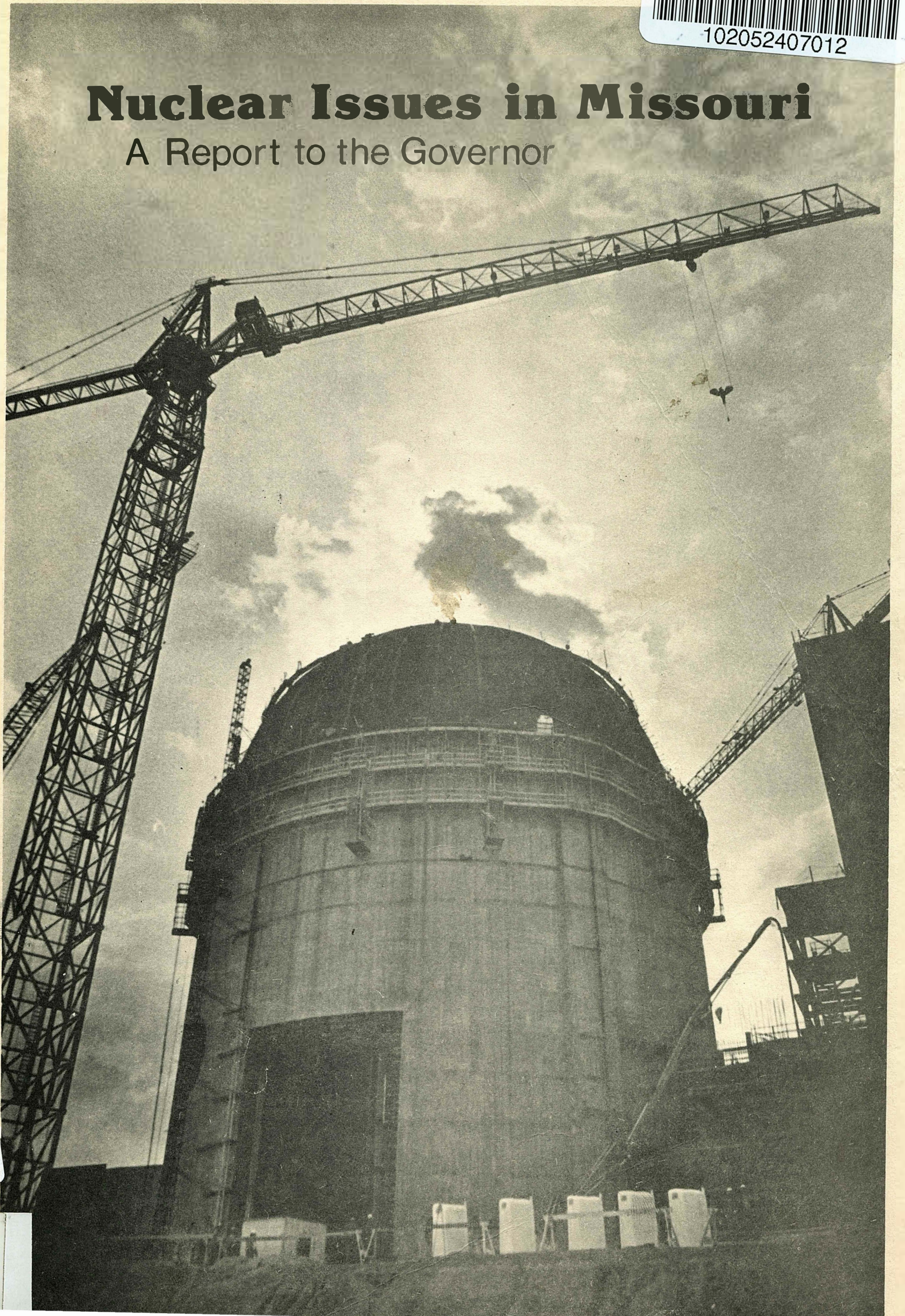
Nuclear Issues in Missouri

A Report to the Governor



April 26, 1979

Honorable Joseph P. Teasdale
Governor of Missouri
State Capitol
Jefferson City, Missouri 65101

Dear Governor Teasdale:

Attached is my report to you entitled, "Nuclear Issues in Missouri: A Report to the Governor."

While the federal government has pre-empted many states' rights in the nuclear field, this report contains many positive recommendations which will help the state regain some control over its destiny, and to help protect the health and safety of its citizens.

Entering the nuclear age is an enormously expensive proposition. The lifetime cost of <u>each</u> nuclear plant is well over $2 billion. Many of the recommendations in this report will be expensive to Missouri taxpayers, many of whom will not receive any of the benefits from nuclear power. Additionally, many Missourians (e.g. in the St. Joseph area near the Cooper Plant) will be exposed to the hazards of nuclear power, again receiving few or none of the benefits. The expense to state and local governments (e.g. for emergencies) will be great, but is presently unknown.

The purpose of this report is not to take a position for or against nuclear power. Instead, it is designed to raise issues of concern to Missourians in the area of cost, safety, health, emergency preparedness, transport of radioactive substances, and disposal of radioactive wastes. This report is a first step toward meeting some of the challenges of nuclear power. Meeting these challenges will require a serious follow-up effort, and a large commitment of time, money and personnel.

I am greatly indebted to Nancy Abrams, Jim Montgomery, and Joel Primack, the many people interviewed, and the Department of Natural Resources staff members who helped in many ways. Responsibility for all facts and opinions stated in this report remain that of the author alone.

Finally, I wish to express my own personal concerns. The three areas which need most attention are a re-examination of: the need for new electricity generation in Missouri, the complete lifetime costs of nuclear power plants, and the emphasis on

near-term costs and savings to consumers. Too often the Public Service Commission, the Office of the Public Counsel, and others are concerned about the expense to ratepayers due to construction delays caused by safety considerations, hearings, and other activities. Yet these expenses may be small compared with other larger, long-term expenses.

I hope you will find this report useful in fulfilling your responsibilities to Missourians.

Sincerely,

James W. Benson

NUCLEAR ISSUES IN MISSOURI

A REPORT TO THE GOVERNOR

April 26, 1979

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INTRODUCTION

Until recently, nuclear energy was described as clean, safe, and affordable. However, the near disaster at Three Mile Island, Pennsylvania, highlighted the continuing disagreements among experts in the field of nuclear energy and uncovered the conflicting information concerning the safety of nuclear energy.

The accident brought to light many aspects of nuclear power that received little attention before. It also spotlighted many questions which had been in the minds of the public as well as officials in positions of authority.

Missouri's Governor Joseph P. Teasdale was one such official. Following the accident at Three Mile Island, Governor Teasdale requested an analysis of nuclear issues in the state of Missouri. Teasdale's primary concerns were issues of safety and costs related to nuclear facilities, especially the Callaway I Plant, in Callaway County, Missouri. His concerns included: construction practices and costs, the transportation of fuel and spent fuel, disposal of radioactive wastes, the state's preparedness to handle severe accidents, and the consequences of such accidents.

The Governor hired a consultant to evaluate possible actions the State of Missouri could take to protect the health and safety of Missourians. In addition, specialists with backgrounds in health physics, state level emergency planning, nuclear physics, evaluation of pressurized water reactor (PWR) safety systems analysis, waste disposal, and conflict mediation were assembled.

Using documents supplied by the Department of Natural Resources (DNR) and other state agencies, a comprehensive

library was collected. Written answers by state officials in response to questions raised by the Governor as well as environmental reports for Callaway, Cooper, and other nearby nuclear power plants were included. Other documents were from the U. S. Department of Energy and the Nuclear Regulatory Commission. Much of this accumulated information will remain on file at DNR or at the Missouri State Library.

Between April 5 and April 25, 1979, the consultant and his team of specialists reviewed relevant documents, interviewed state and university personnel, toured the Callaway Plant, met with the Governor, and wrote their findings and recommendations in a report.

This report is organized into five main parts: Summary, Other Issues, Findings, Recommendations, and Appendices. The Summary highlights the most important findings and recommendations along with related issues. The Other Issues section consists of problems not discussed elsewhere in the report. The Findings are organized into three broad categories: emergency preparedness, routine monitoring of radioactive substances, and issues related to the Public Service Commission. The Recommendations are organized in the same categories. The Appendices contain background information about nuclear power, transportation of radioactive substances, reprints of articles about the Three Mile Island accident, low-level radiation health effects, and high-level radiation health effects, and disposal of high-level radioactive wastes. The Appendices also contain information drawn from the Callaway and Cooper environmental impact reports and other appropriate documents.

SUMMARY

This section compiles the most important issues uncovered during this brief study. As will be seen, some of the issues are not dealt with fully because time did not permit or vital information was inaccessible. It is hoped that the Governor, state agencies, the Missouri legislature, the public and the news media will all contribute to the resolution of these issues.

1. The Governor should assign a staff assistant whose sole responsibility would be continuing the effort begun by this brief study. As other pressing matters come to the fore, there may be less emphasis on following up on this report's recommendations. An assistant to the Governor, with appropriate responsibility and authority, could work with the agencies and legislature to resolve many of these issues.
2. A single agency, and perhaps a single person, should be officially designated by the Governor as a disaster "czar" who would take charge in the event of a nuclear accident.
3. The highest priority for off-site emergency plan development and testing should be given to Nebraska's Cooper Nuclear Plant since this plant currently is operating on Missouri's border.
4. Establish a timetable for the completion of the overall state plan with appendices on the Cooper plant, the Callaway plant, and the transportation of nuclear materials.
5. The state should require that plants be licensed subject to Environmental Technical Specifications in accordance with recent Environmental Protection Agency regulations on radioactive emissions.
6. The Governor should approve the PSC request for six staff members to monitor costs, regulations, and design changes related to construction of Callaway I.
7. The PSC should begin an immediate investigation on the advisability of reopening hearings on the Callaway I certificate.

PART III - FINDINGS

A. EMERGENCY PLANNING AND PREPARATIONS

1. The state's emergency response plan to nuclear accidents is fragmented and untested. The state is ill-prepared, ill-trained, and ill-equipped to handle a major "fallout" from a nuclear accident in regard to radiation protection surveillance, field analysis, control, and decontamination.
2. A serious accident during the transportation of radioactive materials may result in confusion because the authority to respond to such accidents is not currently well-defined.
3. There is a current void in the delineation of various federal and state agency responsibilities to address nuclear policy and emergency issues.
4. The occurrence of a nuclear accident in Missouri without a suitable response plan would unnecessarily risk the public health and safety of thousands of people.
5. The existing lack of coordination between state agencies, as well as between the state and federal governments has hindered the formulation of state and local emergency preparedness plans.

B. MONITORING AND REGULATION OF NUCLEAR ENERGY FACILITIES AND RADIOACTIVE MATERIALS

1. Existing Missouri statutes do not establish a comprehensive radiation protection program. Although some flexibility exists to allow a more aggressive radiological control program, the bulk of the state's activities are passive.
2. Environmental monitoring of radioactive emissions is almost non-existent. An exception is monitoring for gamma radiation near the Cooper plant.

3. A reassessment must be made of the X-ray inspection program in order to determine the adequacy of inspections and their frequencies.
4. The Division of Health's Bureau of Radiological Health currently lacks sufficient personnel and equipment for state environmental surveillance and the monitoring of radioactive material activities.
5. The state of Missouri is not participating under Section 274 of the Atomic Energy Act. This provision allows states to receive authority from the Nuclear Regulatory Commission to regulate the use of certain radiological materials. The decision to participate will likely require a significant increase in general revenue funds, since no federal funds would be available.
6. The control of radioactive material such as radium and the accelerator-produced isotopes has serious gaps.
7. There is no program to adequately inspect, monitor, or even control intrastate shipments of radiological materials.
8. A survey conducted in July and August of 1975 by Dr. David Leuthold at the University of Missouri-Columbia, found that issues related to radioactive materials and nuclear power vitally concern the public.
9. In 1975, the largest amount of nuclear material transported in the state consisted of radiopharmaceuticals.
10. The actual volume of low- and high-level waste material transported in and through Missouri is unknown.

11. There is not a centralized data base in the state which monitors the origin and destination patterns of radiological materials being transported in the state.
12. The Missouri Atomic Energy Commission's activities are obscure to both people in and out of government. (See St. Louis Post-Dispatch, September 5, 1976, and the Kansas City Times, April 7, 1979.)
13. In 1976, Missouri had over 6,000 X-ray machines in the state and the Bureau of Radiological Health has only two full-time, qualified inspectors. The average number of inspections is 450 per man-year.
14. By entering into necessary agreements with the Nuclear Regulatory Commission, the state could inspect packaging and shipments in transport to insure federal compliance.
15. The body of regulations affecting the transportation of radiological materials is not centralized in Missouri or in the federal agencies.
16. State regulations for intrastate shipments of radioactive materials are non-existent.
17. The Nuclear Regulatory Commission's nuclear materials inspection program in the state is infrequent.
18. Information received by the state from the Nuclear Regulatory Commission is poorly coordinated among state agencies which may have appropriate jurisdiction.
19. The Air Conservation Commission has the authority to adopt radiological emission standards, if it so desires.
20. It is not clear which agency should handle the monitoring of radioactive materials. House Bill 888 proposed giving all authority to the Department of

Social Services, which lacks experience in environmental monitoring as well as meteorological analysis, transportation regulation, and evacuation power, (all of which are mandated by House Bill 888). There are problems with H.B. 888; for example, penalties of $1,000/day are inadequate, and "perpetual care" (waste disposal) provisions are very vague.

C. PUBLIC SERVICE COMMISSION ISSUES

1. The Public Service Commission has taken the position that health and safety of nuclear reactors is the exclusive jurisdiction of the federal government. Yet in its report and Order in Case Number 18,117, 14 March, 1975 (Union Electric's application to construct the Callaway Nuclear Plant), the Public Service Commission made a judgment that "the rules and regulations of the Nuclear Regulatory Commission....make the proposed plant safe." (pp. 31 and 33).
2. The Public Service Commission only regulates whether such a facility may be constructed, based on utility company load forecasts and an economic evaluation of other sources of electricity.
3. The Public Service Commission has the authority to investigate or audit utility construction management practices and safety requirements insofar as they affect utility rates.
4. The Public Service Commission has a number of personnel and budget constraints that could affect adequate monitoring of Callaway and Wolf Creek construction practices:
   - Workloads, budget constraints, and limited staff have prevented the Public Service Commission from

active involvement in Nuclear Regulatory Commission proceedings.

In order to properly evaluate Union Electric's request for rate increases as a result of the addition of Callaway, the Public Service Commission will need more specialized staff to monitor acceptable construction and safety costs. A contractor's recommendation to the Public Service Commission would require an appropriation of $225,000 - $300,000 but it was estimated that this could save rate payers $30-$60 million. The PSC requested $129,500 for six new people to monitor Callaway costs.

5. The Governor only approved of one full-time person and $30,000 for equipment expenses.
6. Union Electric may make a decision very soon on building either Callaway II or a similar sized coal-fired plant.
7. All future load forecasts and capacity expansion requirements are highly uncertain due to the unspecified assumptions built into Union Electric's load forecasting methodology; Union Electric's constant high forecasts of peak loads; future Public Service Commission rate design hearings for investor owned utilities in the state; and the delayed impact of National Energy Act conservation and load management programs.
8. Alternatives to base load capacity expansion (e.g. more efficient household appliances,(esp. window air-conditioners), ripple control, co-generation, etc.) have not been adequately considered by the Public Service Commission and utilities.
9. No true comparative costs of nuclear power versus coal power can be reliably derived until a national

policy of waste disposal and decommissioning is developed. However, the Council on Economic Priorities (84 Fifth Avenue, N.Y., N.Y.) has performed a detailed cost estimate for twin 1150 MW plants similar to Callaway. The Council study, which is forthcoming, is a detailed analysis of the employment and economic impacts of developing nuclear power compared to conservation and some solar.

10. Union Electric's method of decommissioning Callaway I is unknown and was not a part of the economic evaluation of the facility. The costs of decommissioning range from $30 million to $150 million and more, depending on the hypothetical method of decommissioning.

11. The Wash-1400 Report was cited in Public Service Commission/Union Electric Callaway hearings as evidence of safety of Callaway units. This report recently came under NRC criticism for having a faulty methodology.

12. The Public Service Commission and the Nuclear Regulatory Commission have an agreement to voluntarily share information of mutual interest.

13. The Callaway I unit was designed to have enough stored, spent-fuel capacity to last 10-15 years. Thereafter, away-from-reactor storage facilities will have to be sited, approved, constructed, and opened. By the mid-1990s, Union Electric will have to locate such a suitable facility or cease operating the Callaway Plant.

14. Any significant change in the Nuclear Regulatory Commission safety standards (e.g. following the TMI Accident) for the operation of a nuclear facility can substantially change the comparative

cost-effectiveness of a nuclear facility versus a coal-fired facility.

16. In the opinion of the PSC General Counsel, the PSC has the authority to disallow the entire cost of a new plant if it is found to be not needed.

PART IV. RECOMMENDATIONS

A. EMERGENCY PREPARATIONS

1. The highest priority for off-site emergency plan development and testing should be given to Nebraska's Cooper Nuclear Plant since this plant currently is operating on Missouri's border. For this reason, the plan development for the Nebraska plant should take precedence over the state's Callaway County plant. Meetings concerning emergency notification of accidents should be held as soon as possible with Nebraska, Atchison County, and plant officials.
2. An assessment must be made of the state's capability to measure radioactive emissions of out-of-state nuclear facilities which could pose a hazardous threat to Missourians in the event of an incident: Cooper, Nebraska; Wolf Creek, Kansas; Black Fox, Oklahoma; Clinton and Quad Cities, Illinois; Arnold, Iowa; Arkansas Nuclear One, Arkansas.
3. Establish a timetable for the completion of the overall state plan with appendices on the Cooper plant, the Callaway plant, and the transportation of nuclear materials. Milestones would include dates for meeting with top state and local officials to assign responsibilities, for completion of a draft plan, for approval by agencies (one full-time person could accomplish this task in six months), and for testing the plan's efficacy.
4. The state should petition the Nuclear Regulatory Commission to require all reactor operators to develop detailed emergency on-site management procedures in cooperation with state emergency planning authorities.
5. The State Radiological Emergency Response Plan should be developed using the guidelines contained

in the U. S. Nuclear Regulatory Commission's "Guide and Checklist for Development and Evaluation of State and Local Government Radiological Emergency Response Plans in Support of Fixed Nuclear Facilities" (NUREG 75/111). By following this guide the state plan should be effective and receive NRC concurrence. In addition, state planners should request a visit and consultation with the federal interagency cadre on emergency response planning.

6. Appropriate state officials should meet with their counterpart in Nebraska in order to determine the quality of the Cooper emergency response plan. The operator of the Cooper plant should be contacted to develop a working relationship and to become familiar with the strengths and weaknesses of their plan and how Missouri would be notified in case of an accident.

7. A direct one-call evacuation order should be established between the utility and the appropriate county official.

   Due to the possible need for timely evacuation of affected off-site areas, the response plan should provide for only one call to be made by the utility to the off-site official who is responsible for evacuation (e.g. the county sheriff). A formal written agreement will be needed giving the utility authority to do this. To avoid the liability of actually ordering the evacuation, the utility could advise the sheriff of its best estimate of the incident and the sheriff then would make the evacuation decision.

8. Estimates should be made of the cost of handling emergencies (including the worst case), for the areas around Cooper and Callaway. Most costs would be borne by the localities. Cost estimates should be made for both localities and the various state agencies. A determination of cost liability should be made.

9. A realistic, full-scale exercise of the response plan should be held as soon as possible. The exercise should involve appropriate state, county, and city officials. In addition, the exercise should include hospital drills simulating the influx of persons needing immediate radiation treatment.

   The plan can be evaluated and improved on the basis of this exercise. All persons having emergency response assignments must be informed of any and all plan changes.

10. Radiation Protective Action Guides (PAGs) should be short and quantitative.

    It is recommended that the EPA PAGs be used. State emergency response officials should be able to quantify and verify a utility's on-site estimates of radiation dosage in order to determine the proper PAG to use.

11. Routine meteorological studies of expected patterns of plume movement and studies of radioactive contamination of water and soil following releases of radioactivity are advised. These studies, which could be performed by staff in the Department of Natural Resources' Division of Environmental Quality, should be included in emergency plans.

12. In accordance with recent recommendations from the U. S. General Accounting Office (GAO), no nuclear power plant should receive an NRC license without an approved and tested off-site emergency response plan.

13. The state should consider contracting for an investigation of construction practices by a qualified, independent inspector. Serious questions about the adequacy of the Nuclear Regulatory Commission's inspection program have been raised in the recent GAO Report EMD-78-80, September 7, 1978, "The NRC

Needs to Aggressively Monitor and Independently Evaluate Nuclear Powerplant Construction." Many questions also have been raised regarding alleged unsafe construction practices at the Callaway Plant.

14. The state should petition the Nuclear Regulatory Commission to consider all classes of possible serious accidents in new, detailed studies using fault tree and all other applicable analysis techniques before licensing Light Water Reactors (LWRs). The Nuclear Regulatory Commission should perform detailed studies of several promising technical devices which could mitigate the consequences of such accidents, such as controlled filtered release devices as suggested in the APS Report, Appendix II, Section Gl, p. 5110. See also the decision of the California Energy Commission on Underground Nuclear Plants and supporting documents, and especially the detailed study, "Post-Accident Filtration as a Means of Improving Containment Effectiveness," by B. Gossett, D. Okrent, et. al. UCLA-Eng-7775 (Dec. 1977).

15. The Nuclear Regulatory Commission should require adequate instrumentation in all LWRs to allow detailed monitoring of all possible accident conditions. Another requirement should be a redesign of reactor control rooms to improve operator understanding and control of abnormal situations. A number of serious and unresolved safety issues regarding nuclear reactors have been identified by the Nuclear Regulatory Commission. The state could help speed resolution of these issues by expressing its concern. (See APS Report, especially Ch. IV, Sec. D, pp. 530-31).

16. The Nuclear Regulatory Commission should require all nuclear power plant operators to have at least a four-year college degree (perferably in engineering), be thoroughly tested on simulators for all conceiv-

able accident conditions, and be periodically re-certified.

17. The state should petition the Nuclear Regulatory Commission to conduct a detailed study of water contamination dangers from core-melt accidents. These dangers are quite substantial. See APS Report, Appendix II, Sec. E 8, p. 5109 and WASH-1400, Appendix VII.

18. The state should petition the Nuclear Regulatory Commission to require all commercial reactor owners to establish emergency stockpiles of iodine, preferably in the form of potassium iodide tablets, to be issued to everyone potentially in the path of a large release of radioactive iodine. Approximately 100 mg. of potassium iodide will block uptake of radioactive iodine by the thyroid, thus helping to prevent thyroid nodules in the exposed population. See Report to the American Physical Society by the Study Group on Light-Water Reactor Safety. Reviews of Modern Physics, Vol. 47, Supp. No. 1, Summer 1975, pp. 5109-110. (Referred to elsewhere as APS Report).

19. A single agency, and perhaps a single person, should be officially designated by the Governor as a disaster "czar" who would take charge in the event of a nuclear accident. This person should be a qualified, knowledgeable individual who has an established working relationship with state, local, and utility officials. This action will insure that there is no hesitation when emergency orders are given by the state.

20. The state should consider having some expertise in the form of a special assistant or a designated agency official available to advise the Governor in the event of an accidental or unplanned release of radiation.

21. A special assistant to the director of the Department of Social Services as part of the radiological health program or to the director of the Department of Natural Resources as part of the environmental protection program would provide Missouri with needed expertise within state government. This person should lead an inter-agency planning group with representatives from the Department of Natural Resources, Public Service Commission, the Division of Health, the Disaster Planning and Operations Office, and the Missouri Atomic Energy Commission. This group should establish a formal mechanism for communicating with the Nuclear Regulatory Commission and appropriate utility companies.
22. The state of Missouri should hire a graduate-level radiation health physicist to develop and conduct a statewide radiological environmental monitoring program on both a routine and emergency basis. To properly conduct this program, the state would have to fund a radiation counting laboratory complete with equipment and support personnel, including a radiation chemist and a technician.
23. Agreements should be formalized for radiological assistance from the Missouri Radiological Assistance Team or "MO-RAT," a team operating through the University of Missouri and other institutions. University personnel, trained in radiological sciences, can provide valuable assistance in the event of an emergency. However, they must know what is expected of them. Their assistance at the accident scene should be coordinated by state officials equally knowledgeable about radiological emergency procedures.

B. MONITORING AND REGULATION OF ROUTINE CONDITIONS

1. A monitoring effort, presumably within the Department of Natural Resources' Division of Environmental Quality, should be established and charged with measuring radioactive releases from nuclear facilities in the state. Fees for operating expenses should be levied against these facilities.
2. The state should establish reporting requirements for abnormal as well as expected emissions. Plant operators should be required to notify the state authority immediately of any emissions more than 10 times above nominal. In addition, any emission above nominal should be reported within 24 hours. (Note: NRC requires immediate notification only for emissions 5,000 times nominal. See 10 CFR 20.403.)
3. The state should require that the plant operator allow routine and unannounced access to instruments and on-site records regarding emissions.
4. The state should require that plants be licensed subject to Environmental Technical Specifications in accordance with recent Environmental Protection Agency regulations on radioactive emissions (for example, 25 millirem (mrem) maximum body dose per year for any member of the general public from all aspects of the nuclear fuel cycle). These Environmental Protection Agency regulations, effective December 1, 1979, are in 40 CFR 190.10. Note that the Environmental Statement for the Callaway Plants (NUREG-75/011, March 1975) specifies that normal emissions from the plant will be well within these limits, as well as the somewhat less stringent limits specified in 10 CFR 50-34. But the NRC Draft Radiological Effluent Technical Specifications for Pressurized Water Reactors (PWRs) (NUREG-0471, revision 1, October 1978) appear to comply with neither 10 CFR 90 nor 40 CFR 190, but only with the

less stringent (500 mrem per reactor per year) limits in 10 CFR 20.

5. The state of Missouri should inquire whether the Nuclear Regulatory Commission is intending to conduct licensing of the Callaway Plant according to Environmental Protection Agency regulations. If not, the Nuclear Regulatory Commission should provide a detailed description of the basis of its decision.
6. The state needs to reassess the adequacy of Missouri's vital statistics data. Data are to be gathered in order to measure the incidence of diseases which may result from the increased use of nuclear materials in any area. In particular, there should be a mandatory system devised to report and track the incidence of all cancer cases and deaths in Missouri.
7. A detailed evaluation should be made of the Bureau of Radiological Health's data processing regarding the transportation, storage, location, handling, and disposal of radiation sources presently under state control. An assessment also should be made regarding new sources under state control, if Missouri decides to become an "agreement state."

C. MISSOURI PUBLIC SERVICE COMMISSION ISSUES

1. The Governor should approve the Public Service Commission request for six staff members to monitor costs, regulations, and design changes related to construction of Callaway I. The regulatory role of the PSC requires constant monitoring and updating of the cost of construction, federal and state regulations, and the continuing change of nuclear plant design. This monitoring will enable the PSC to determine which costs to include in consumer rates upon completion of the plant. The 1980 PSC budget included a request for six additional staff

members at an annual cost of $129,500. This cost is very small in relation to the potential consumer savings to be realized from such a cost monitoring program.

2. The PSC should begin an immediate investigation on the advisability of reopening hearings on the Callaway I certificate. It is the opinion of the General Counsel of the PSC that the commission has retained jurisdiction to the extent that the commission may reopen hearings at any time before completion if the facts upon which the original certification was granted have materially changed. Possible reasons for reopening the hearings could be continually lowered load forecasts, default of the Westinghouse fuel agreement, the Nuclear Regulatory Commission rejection of portions of WASH-1400 (the Rasmussen Report),* the Environmental Impact Statement's lack of treatment of class 9 accidents (similar to the Three Mile Island class of accidents), lack of inclusion of decommissioning costs, lack of policy and methods of ultimate waste disposal, determination of whom to charge for purchase of replacement power in the event of a serious accident, determination of cost and possible delays due to new design features resulting from the TMI accident, insurance and rate considerations related to accidents, the U. S. General Accounting

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*The Missouri PSC apparently rested a large part of its decision that nuclear plants are safe on testimony presented to it by nuclear engineers from the University of Missouri, which was based in turn on the AEC/NRC Reactor Safety Study (Rasmussen Report). Since this study has now been seriously questioned by NRC reviewers (Risk Assessment Review Group Report to the NRC, NUREG/CR-0400, 9) and has been partially repudiated by the NRC, the PSC may wish to reconsider its earlier decision.

Office study (EMD-78-80) of the laxity of Nuclear Regulatory Commission safety inspections during construction, and possible problems related to seismic design criteria. Considerations for not reopening the hearings include a possible lawsuit by Union Electric to stop the PSC from reopening the hearings (which could result in delays) and increased costs to consumers due to delays if the hearings were held.

3. The Public Service Commission should inquire into the full costs of nuclear power plants including the increasing costs for safety, such as retrofits and scheduled outages for retrofits required by the Nuclear Regulatory Commission; decommissioning; and ultimate waste disposal. Unusual and unanticipated costs could be tied to insurance to prevent either a pass-through to consumers or bankruptcy of the utility (in the case of an accident like TMI). The state should require the plant to be insured for losses due to safety shutdowns of any kind, whether required by the Nuclear Regulatory Commission or caused by an accident. The state is not preempted in matters relating to <u>costs</u> of safety.

4. PSC's criteria for determining what utility costs may and may not be passed on to consumers should be clearly stated in law. The cost of buying outside power when a nuclear plant is out of operation due to an accident would be included; these costs should not be passed on to consumers. The costs of decommissioning a plant should not be passed on to ratepayers after the life of the plant has ended (this is the other side of construction work in progress (CWIP) similar to ratepayers paying for something they are not receiving). The utility should be required to build up a state-controlled trust fund, sufficient

to cover all decommissioning and ultimate waste disposal costs.

5. The result of the Three Mile Island incident will cause a number of Nuclear Regulatory Commission rule changes. The state of Missouri will need to designate a key person to keep track of the changes and the implications for the costs of Missouri reactor facilities.
6. The state should have outside consultants prepare a study on the relative benefits, needs and costs of coal vs. nuclear in Missouri. The potential of conservation and peak load pricing to reduce peak loads also should be studied.
7. The PSC should require Union Electric to perform a new, detailed cost estimate of the Callaway plants. A detailed breakdown of the costs and all assumptions should be published for public review.
8. The staff and budget of the Public Counsel should be increased in order to better enable the office to critique load forecasts, construction practices and the economics of other sources of energy (including conservation).

OTHER ISSUES

Until recently, nuclear energy was described as clean, safe, and affordable. Nuclear power is not clean. Radioactive substances pose health threats unlike any other substances, to the present and all future generations. Nuclear power is not entirely safe. The Rasmussen Report (WASH-1400), the main Atomic Energy Commission analysis of reactor safety, has been found to be flawed and optimistic. The report does not consider serious accidents such as a meltdown. It was promised that electricity would be "too cheap to meter," yet taxpayer subsidies and unaccounted for costs (e.g., insurance, decommissioning, waste disposal) are largely responsible for the appearance that nuclear power is an economically competitive alternative to traditional sources.

The near disaster at Three Mile Island (TMI) brought these and other problems to the attention of the public. In the past, information about nuclear power has come from utility company officials, nuclear energy trade associations, the nuclear power industry itself, and from the nuclear engineering departments at colleges and universities. Many of these "experts" have received their training from the industry or were subsidized by academic or research programs of the former United States Atomic Energy Commission.

These nuclear "experts" often knew little about the detailed inner workings of full-scale, commercial nuclear power reactors. They traveled the country telling audiences that a person is more likely to be hit by a meteorite than to be harmed by a nuclear reactor accident. They said the chance of serious accidents were one in millions. These statistics were based on the Rasmussen Report, which was recently discredited by an NRC sponsored evaluation. Until the very day of the Three Mile Island accident, experts were saying that the possibility of a meltdown existed only in the imaginations of the critics of nuclear power.

During the near meltdown at Three Mile Island, the public was exposed to the spectacle of plant operators who refused to admit the severity of the problem and who were later required to yield authority to NRC personnel. The five leading nuclear "experts," the Commissioners of the NRC, were operating, as they later admitted, in the "blind." The governor of Pennsylvania and the public were constantly given conflicting reports.

The accident has brought to light many aspects of nuclear power which received little attention before. In the past, much attention was given to the industry complaint that the NRC was regulating too much, to the detriment of rapid expansion of nuclear power. It is now known that NRC licensing and operating regulations are lax and often blatantly ignored. Nuclear power plant operators are required to have only a high school diploma and "two years" involvement in operations, construction or design at some kind of power plant" (not necessarily nuclear). They are not required to be trained to handle severe accidents. NRC safety inspections of plants under construction are lax to non-existent, according to the United States General Accounting Office.

Power plant safety systems are not designed to handle the most serious class of problems. Nuclear power plant Environmental Impact Statements do not even consider accidents as severe as the one at Three Mile Island. Emergency preparedness plans are superficial to non-existent in most states with nuclear reactors.

This section of the report consists of issues not discussed elsewhere in this report.

1. The Public Service Commission hired members of the University of Missouri's nuclear engineering department (Professor Walter Meyer, et. al.) to testify as "unbiased, objective experts unconnected with the case" during the Callaway hearings.

   A 1975 audit of the PSC by the State Auditor disclosed that the University experts were lecturing about "This Atomic World," under a contract with Union Electric, at the time of the hearings. The auditor chastised the PSC for hiring "consultants so closely involved with principals of the case."

   In defending itself, the PSC said, "It must also be recognized that it is impossible to obtain entirely unbiased testimony on issues of this type." (See the Appendix for a copy of the Auditor's findings.)

2. A most disturbing and unresolved issue came to light during this study. A former employee of a subcontractor to the Callaway plant came forth with the following account. In order to protect the identity of this person, "Ms. X" will be used when referring to her.

   Ms. X stated that she had been employed by a subcontractor working on components for both the Callaway and Wolf Creek plants, since both have the same design and are being fabricated under one set of specifications. Ms. X has a four-year college degree and is intelligent and articulate. After a long conversation about the details of her employment and background, there was no apparent reason to doubt the validity of her account.

   Ms. X stated that her main concern resulted from a confusion in the delivery of all steel gaskets. The factory manufacturing the gaskets sent some gaskets of carbon steel and some of stainless steel, but marked them all as stainless. The factory attributed the confusion to quality control problems.

The carbon steel and stainless steel gaskets were separated as well as possible with only an uninformed, visual inspection. Ms. X estimated that 10% or more of the gaskets were interchanged. While she did not know the specific operational problems that might result from this interchange, she feared that the carbon gaskets would corrode more rapidly than the stainless steel gaskets. Most of these gaskets were installed in the radwaste and auxiliary buildings.

Ms. X's supervisors told her not to worry about the problem.

Another example of negligence cited by Ms. X involved a delivery of valves which were incorrectly coded. A young, inexperienced clerk was assigned to correct the mistake on hundreds of valves. This assignment put the clerk in a position of making decisions he was not qualified to make. The number of mistakes - by the manufacturer and by the clerk - is unknown.

Remarking on NRC audits, Ms. X said the NRC usually accounced its visits in advance, allowing workers to clean up and prepare their areas for the inspection. On-site Quality Assurance people guided the NRC inspectors, who took little initiative in seeking out problems. Because of the way these inspections were conducted, Ms. X observed that problems often were overlooked. One such instance involved welding. To provide a special mix of metal to the weld, some welds required the use of two welding rods at the same time. Primarily performing this intricate work were local farmers earning extra income, who paid little attention to detailed requirements.

Ms. X also related incidents where several formations, made up of smaller components such as pipes and valves, arrived at the construction site after being damaged in transit. A few of the larger formations, transported by flatbed trucks, had to be returned for repairs after they failed to clear concrete highway bridges. Ms. X

reported the repairs to be superficial; no X-rays were taken to determine whether internal or structural damage occurred.

Rules often were bent or ignored to keep the cash flow up, according to Ms. X. Many components have to be cataloged and tested before shipment. But on many occasions, materials were released before the testing and paperwork were completed.

Ms. X also was greatly concerned with workers' insensitivity to the possible ramifications of shoddy work. She admitted she often signed blueprints, knowing they contained mistakes.

She predicted problems arising at the Callaway and Wolf Creek plants after power production begins. These two plants, the first of this design to be built, contain many mistakes, according to Ms. X. She said many mistakes would be corrected on units 3 and 4, and that unit 5 would be even better. (As of this writing, units 4 and 5 may have been cancelled because of the TMI accident.)

The film "China Syndrome," and the Three Mile Island accident brought Ms. X forward. She said she saw too much of her own experience reflected in the film and the accident to remain quiet any longer. She said she now realized how susceptible these large plants are to both human and hardware failures; she originally thought the problems she witnessed were too inconsequential compared to the massiveness of a nuclear power plant.

3. Other less substantiated accounts of pumps and motors being incorrectly installed, of control and instrumentation wiring being laid without proper blueprints, and other incidents have been received.

At the present time, there is no reason to doubt that most of these accounts are true. According to these accounts and to the U. S. General Accounting Office's study of NRC safety inspections (referenced elsewhere in this study), there is cause for alarm. If the Callaway hearings are reopened, it may be possible for

the PSC to claim jurisdiction for safety inspections in the event that the NRC is found to be acting irresponsibly.

4. It is widely believed that the federal government has completely pre-empted the states in the field of nuclear energy. Yet, as this report shows, there are many ways in which the states can take a leadership role.

   Before matters became so pressing and so close to home, it was easy to ignore many of the problems. There was a feeling that "they" (meaning the federal government) were doing something about the problems. This attitude has been partly responsible for the gradual erosion of many of the most important states' rights - especially the states' responsibility to protect the health and safety of its citizens. In the nuclear field, the federal government has encroached the most upon this right. However, it is also easy to think of the federal government as a monolithic institution, beyond the reach of its citizens. If the citizens are sufficiently concerned, they should be able to get their representative government to respond to them.

5. The nuclear industry usually does not portray high-level waste disposal as a problem. Representatives of the industry claim that technology exists to permanently isolate high-level radioactive wastes from the environment. The real problem, according to these industry spokesmen, is the failure to make a political decision to implement a storage program.

   This line of reasoning implies 1) that a technical method of disposing of the wastes exists today, 2) that people simply do not want to use this technology to dispose of the waste, and 3) that a majority of the elected officials responsible for these decisions are arbitrarily withholding a decision to begin a program.

   As the article from a recent issue of <u>Science</u> shows (see the Appendix), there currently is no known method to safely dispose of these wastes.

Secondly, most of the people involved in the nuclear issue, pro and con alike, realize that there are wastes which must be disposed of, simply because they already exist. The U. S. Department of Energy, responsible for the design and manufacture of all nuclear weapons, produces a large quantity of high-level wastes, as do all commercial nuclear power reactors.

Finally, it is highly doubtful, even assuming that a proven technology exists, that a majority of our elected officials are intentionally withholding a decision to permanently isolate these wastes.

The operating life of a nuclear plant is generally assumed to be 30 years. It is the consensus of most scientists that a solution to the waste disposal problem is at least 20 years away, if permanent isolation is indeed possible at all. Callaway's storage capacity for spent fuel will be 10 - 15 years. The attitude of the nuclear industry could be summarized as follows. Answering a question about what UE plans to do with its wastes, Donald Schnell, manager of nuclear engineering, said "We're dependent on the federal government . . .". (Daily Capital News, April 18, 1979). If the PSC reopens hearings on Callaway, the lack of a solution to this problem should be closely examined.

6. Interviews with the PSC staff and a review of load forecast studies revealed that the PSC is not capable of fully understanding the forecasts of electricity demand that are submitted by Union Electric Co. and other utilities. Without the capability of challenging forecasts and preparing independent forecasts, PSC has to accept UE forecasts at face value.

   In 1973, UE predicted that its peak load would be 9,407 megawatts in 1984. In 1974, it forecast 8,777 megawatts in 1984 and in 1975, 8,418 megawatts.

   Although UE has made major changes in its methods and assumptions, it still appears that the forecasting methodology is primitive and too aggregated to be accurate.

According to PSC staff, UE officials responsible for the forecasts state that no detailed, written description of the forecast methodology, assumptions, or justification for each assumption exists.

Many states require utilities to report annual forecasts, which must be accompanied by a detailed description of the methodology and assumptions used to make the forecasts. The states then can knowledgeably verify the accuracy of the forecasts or change assumptions to determine the impact on demands (e.g. the number and efficiency of window air conditioners).

It is difficult to believe that UE does not have the detailed methodology and assumptions. Missouri should follow the lead of other states and require that this information, in its entirety, be made available to the public immediately. If the utility cannot produce this documentation, all its forecasts are suspect and indefensible.

Until this information is released, no further rate hearings should be held and no new rate designs determined.

7. A full range of energy conservation, alternate energy source, and base-load and peak-load options must be considered in major rate design hearings; the PSC does not appear to have the expertise to recommend or defend such options.

   The rate design hearings, especially for UE, should be delayed until the PSC can demonstrate its expertise in all these areas. Because the National Energy Act requires these options to be considered in new rate design hearings within the next two years, the public would be better served if upcoming hearings were delayed.

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An Introduction to Nuclear Power

Commercial nuclear power grew out of the nation's efforts to build an atomic bomb in World War II. The first nuclear reactors were contructed during the Manhattan Project to manufacture plutonium for the first atomic bombs. Even then, many scientists could see the enormous potential of nuclear power as a commercial energy source. After the war, much of the atomic research and development capacity built up during the war was gradually redirected towards peacetime applications. The first commercial nuclear power plants began generating electricity around 1960. By September 1978, some 72 reactors were contributing roughly 12% of the nation's electricity.1/ Another 144 reactors were planned, under construction, or undergoing testing. The number of reactors expected to be operating by the year 2000 is estimated between 200 and 500.

Through the 1950s and 1960s, nuclear power was hailed as the energy source of the future. Proponents claimed that nuclear-generated electricity would be "too cheap to meter." Nuclear reactors released none of the air or water pollutants of fossil-fueled plants and were believed to be environmentally superior. While intelligent observers knew that fossil fuels were running short, nuclear power appeared to be a virtually inexhaustible resource.

Only in the last decade has the efficacy of nuclear power been seriously challenged. The costs of nuclear power have risen much higher than once anticipated, and its economic advantage over other energy sources is disputable. Recent epidemiological research suggests that routine, "safe" releases of radioactivity into the biosphere may be responsible for significant increases in cancers and genetic injuries.2/ Nuclear reactors produce enormous quantities of highly radioactive wastes that must be stored for hundreds of thousands of years under fail-safe conditions. The operational safety of nuclear power plants, especially in light of the Three Mile Island accident, has not been clearly established. Until the safety of nuclear reactors has been definitively proven, the possibility of catastrophic accident will continue to be a significant concern. And finally, nuclear plants and the plutonium they produce could be the target of terrorist activities. Plutonium, which is produced in the reactor, can be fashioned into bombs and is also one of the most lethal substances known.

The essence of the nuclear power dilemma was summed up by Dr. Alvin Weinberg, former director of the Oak Ridge National Laboratory,

> We nuclear people have made a Faustian compact with society; we offer an almost unique possibility for a technologically abundant world for the oncoming billions, through our miraculous, inexhaustible energy source; but this energy source at the same time is tainted with potential side effects that, if uncontrolled, could spell disaster.3/

What is Nuclear Power

Reduced to its most basic function, a nuclear reactor generates heat. A nuclear reactor serves the same function as a boiler in a fossil-fueled plant. Both heat water to steam which then turns a turbine to generate electricity.

The qualities which distinguish nuclear power are the compactness of its fuel and radioactivity. The uranium fuels which power a nuclear plant can deliver 20,000 times the heat of an equivalent amount of coal.[4/] Uranium itself is radioactive and the operation of a reactor creates large quantities of radioactive waste. At all points of the nuclear fuel cycle - from the mining of uranium, to its fabrication into fuel rods, to its use in the reactor, to its ultimate disposal - there is the risk of a major release of radioactivity which could endanger public health.

Nuclear power releases energy by converting matter into energy, in accordance with Einstein's famous equation $E=mc^2$. One isotope of uranium, Uranium-235*, will split (or "fission") into two smaller atoms if it absorbs a neutron or if it is hit by a neutron. In the process, about 1/10th of 1% of the mass of the Uranium-235 nucleus will be converted into energy. When fissioned, a Uranium 235 atom will also emit more neutrons, which can collide with and split more neutrons. This process is called a "chain reaction."

In the early atomic bombs, the chain reaction fissioned the U-235 atoms extremely quickly, so that an enormous amount of energy was released in a fraction of a second.

In a nuclear reactor, the chain reaction is controlled so a steady sustained flow of power is generated. The heart of the reactor, the "core," is contained within a closed steel vessel something like a large water tank. Inside the core are <u>fuel rods</u> and <u>control rods</u>. The fuel rods consist of uranium pellets, about the size of a pencil eraser, packed inside long tubes made of a zirconium alloy. The chain reaction takes place within and between the fuel rods. The control rods are made of either boron or cadmium, neutron-absorbing materials. When the control rods are shoved fully into the core, they absorb all the neutrons and the chain reaction stops. The rate of the chain reaction depends upon the number of control rods and the extent to which they are withdrawn.

The core is always kept covered with water. The water serves two functions. First, it acts as a moderator. The neutrons released by fission are moving extremely fast, so fast that they cannot be absorbed by other Uranium-235 atoms and so result in a chain reaction. Water slows down the neutrons to a speed where they can be captured by U-235 atoms. Second, water absorbs and carries off the heat generated within the core.

Leading into and out of the steel vessel are two pipes, one located near the bottom of the tank and the other near the top. Cool water is pumped into the vessel through the lower pipe. The water circulates through the core and is heated. In a <u>boiling water reactor</u>, the water turns into steam, flows out of the upper pipe

and out of the containment dome as steam and drives a turbine electric generator. In a pressurized water reactor, the water circulating through the vessel is kept under so much pressure that it heats to several hundred degrees F without boiling. This heat is eventually used to generate steam to run a turbine.

Operating the reactor is but one step within the nuclear fuel cycle. Raw uranium ore must be taken through several steps before it can be loaded into the reactor. The first step in the fuel cycle is mining. Large deposits of uranium oxide (U_3O_8) ore can be found in the west as well as in Canada, Australia, France, and the Soviet Union. Depending on its quality, the ore can contain up to 3% uranium. Mined uranium ore is then milled, the ore is crushed, washed with water, and treated with sulfuric acid to separate the uranium oxides from other minerals in the ore. One ton of ore will yield about four pounds of this yellowcake, uranium oxide. The remaining 1996 pounds, called mill tailings, are radioactive.

Before the yellowcake can be fabricated into fuel rods, it must be enriched. Only Uranium-235 can fission, and even then, only when at concentrations of about 3% or greater. Natural uranium oxide is only about 0.7% U-235; most of the remainder is nonfissionable Uranium 238. In the enrichment process, U-235 is concentrated to about 3%. From there, it is fabricated into fuel rods. The fuel rods are transported to the reactor and loaded into the core. When the fuel rods are "spent," (i.e. most of the U-235 has been fissioned), the rods are taken out of the reactor for disposal or reprocessing. In reprocessing, the remaining, useable U-235 and the fissionable Plutonium 235, also formed within the rod, are separated for refabrication into new fuel rods. The remainder of the intensely radioactive spent fuel must be disposed of. This completes the fuel cycle.

All energy sources, of course, go through a fuel cycle. Petroleum, for example, is pumped out of the ground, transported to a refinery, refined, and delivered to power plants, industries, and gas stations. But the nuclear fuel cycle is made especially significant by radioactivity. At all points in the fuel cycle, some radioactivity is involved. It ranges from the high-level radioactivity in handling, storing, and reprocessing the spent fuel rods to the low-level radioactivity in mining and milling. Workers are or can be exposed to radiation anywhere in the fuel cycle. Some radiation (mostly low-level) is released routinely into the environment at several points in the fuel cycle and can cause exposure to the general public. These routine releases are supposed to be monitored and regulated by the federal government.

Radiation also can be accidentally released into the environment anywhere along the fuel cycle. But the most basic concerns are reactor operating hazards, safeguarding radioactive (especially fissionable) fuels, transportation of radioactive materials, and waste disposal. Accidents can be caused by technological failures, earthquakes and other natural disasters, and human actions ranging from carelessness to terrorism. A major accident at the reactor, fuel reprocessing plant, or storage facility could release huge quantities of radiation with catastrophic consequences to public

health. The safety of nuclear power is contingent upon knowing the likelihood of all types of accidents and the quantities of radiation that would be released as a consequence so that protection measures can be taken.

The dangers of radiation are only partially understood. Radiation itself is a consequence of radioactivity. Radioactive particles are inherently unstable. By emitting energy in the form of radiation, they can transform themselves into stable atoms. The three most important types of radiation are <u>alpha particles</u>, <u>beta particles</u>, and <u>gamma rays</u>. Alpha rays and beta rays are both moving particles. In alpha radiation, the particle consists of two protons and two neutrons. In beta radiation, the particle is an electron. A gamma ray is an electro-magnetic wave, like radio waves or visible light or X-rays, rather than a moving particle. A radioactive element will always emit the same kind of radiation. Thus, plutonium always releases alpha particles, while Cesium-127 and Cobalt-60 always emit beta particles and some gamma radiation. Consequently, different radioactive substances pose varying degrees of hazard, depending upon the type as well as quantity of radiation emitted.

The health effects of radiation are of three types: 1) general life-shortening, 2) cancers, and 3) genetic damage. That radiation can cause these health problems has been unequivocally established.5/ The point of dispute is determining what radiation exposure levels are either "safe" or present an "acceptable" level of risk. Proponents of nuclear power generally argue that there are "threshold" levels of radiation exposure below which radiation-induced health problems will not materialize. Others argue that a safe threshold level does not exist because even very minute doses of radiation are capable of causing cancer or genetic damage.

The nuclear safety issue thus breaks down into two major questions: What are the chances for the catastrophic release of radiation at any point along the fuel cycle? Are the quantities of radiation routinely released into the environment acceptably safe, or do they in fact endanger the public health? Both questions are largely technical. In theory, it should be possible to determine the probability of catastrophic accident. In theory, scientific research should be able to decide if there is a threshold and what it is. In actuality, an enormous amount of research has been devoted to these questions and there is no consensus as to their answers. Nor is there any indication that a consensus will be reached in the near future. Underlying these technical questions are two subjective issues, which legitimately concern all people, not just scientists. The first question is "What constitutes acceptable risk?" Nothing in this world is 100% safe. Consequently, nothing can be legitimately deemed "safe" unless it can be referenced back to a generally accepted standard of safety. The other value judgment that has to be settled is "What constitutes an acceptable level of certainty?" Just as nothing is 100% safe, so scientific findings are never 100% certain.

Probabilities can be assigned to different types of nuclear accidents, but how do we know how accurate they are, and is this degree of accuracy or certainty sufficient? This question is

especially vexing in assessing nuclear power where there is a very small chance for an incredibly dangerous accident. The question of certainty also pertains to the efficacy of federal regulation and the performance of the nuclear power industry. The public has to be guaranteed, to an acceptable degree of certainty, that safeguards are being properly executed so that real-world safety does in fact conform to the generally accepted standard.

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Transportation of Radioactive Materials

Every year, approximately two and a half million packages of radioactive materials move around the country by truck, railroad, and passenger plane. About 80% of these packages consist of slightly radioactive materials for medical and industrial use. But the remaining shipments---connected with commercial power reactors and with government research and weapons production---include the most radioactive and dangerous materials. Several thousand shipments per year consist of materials being shipped to and from commercial nuclear power plants. By the year 2000 the number of shipments to and from nuclear plants is expected to increase by five to ten times the present level.1/

Radioactive materials are shipped at several different stages of the "cycle" that supplies fuel to nuclear power plants. First, the uranium ore is mined and milled at sites in the West and Southwest. The milled uranium (yellowcake) is then transported to enrichment plants. (It was at this stage that a tractor-trailor overturned and spilled some 10,000 points of radioactive yellowcake onto the highway in southeastern Colorado in 1977). The enriched uranium is then shipped to fuel fabrication facilities, most of which are located in the East. From the fuel fabrication plants, the "fresh fuel" is shipped to nuclear power plants all around the country. Each reactor requires about six truckloads of fresh fuel per year.2/

After the fuel has been burned in the reactor, it becomes many thousands of times as radioactive as fresh fuel. "Spent fuel" is so hot that it must be cooled for half a year before it can be transported. Even after that time, a truckload of spent fuel contains about as much radioactivity as that released by the Hiroshima bomb.3/

In theory, the next stage in the fuel cycle is the transport of the spent fuel to a reprocessing plant, where the uranium and plutonium are recovered to be recycled into fresh fuel. However, there currently are no commercial reprocessing facilities in the United States. The three which were built in the 1960s and early 1970s were all shut down after one of them, the Nuclear Fuel Services reprocessing plant at West Valley, New York, leaked radioactive wastes and became uneconomical to operate. Some spent fuel from government research reactors and weapons production is being transported to government-owned reprocessing plants, located in South Carolina, Idaho, and Washington. But the government plants do not reprocess spent fuel is accumulating in temporary storage pools at the reactor sites. By the 1980s there may be a serious shortage of the storage space since a 1000 megawatt nuclear reactor produces about ten rail or forty truckloads of spend fuel per year.4/

After reprocessing, what remains of the spent fuel is called "high-level waste." This is the most radioactive and dangerous of all. Scientists have not yet determined how or where to dispose of high-level waste safely; it contains radioactive isotopes such as plutonium which must be kept out of the environment for the thousands of years it takes to decay to safe levels.5/ There are currently no shipments of high-level waste. The waste produced at government reprocessing facilities is being stored at the reprocessing sites.6/

The U. S. Department of Energy suggests that shipping of commercial spent fuel and high level waste may begin sometime in the 1980s.7/ If it does, the number of highly radioactive shipments per year will increase dramatically.

Another product presently being shipped from nuclear power plants is low-level waste. This includes "slightly" contaminated trash, equipment, and residues that are shipped to commercial burial grounds in South Carolina, Illinois, Nevada, and Washington.8/

Shipments of uranium, fresh fuel, low-level waste, and spent fuel travel mainly by truck and rail. The shipments are concentrated in the east, southeast and middle west, where the majority of the country's nuclear power plants are located. Traffic in the South Carolina-Tennessee-Illinois-Kentucky area is particularly heavy. Many shipments also travel route I-95, through the heavily urbanized northeast corridor.9/

The radioactive packages are handled and loaded by ordinary methods, and travel unescorted over unrestricted routes. Fresh fuel is shipped in special steel containers. Spent fuel and high-level wastes must be shipped in massive, lead-shielded casks. These casks are designed to be leak-proof even under accident conditions, since security in an accident depends entirely upon the strength of the cask. Low-level waste is shipped in ordinary containers such as metal drums and wooden boxes. 10/

Transportation of nuclear materials involves several types of risk. A small amount of radiation is inevitably released during the course of normal, accident-free transport. If workers or handlers make an error in packaging or loading the material, a more significant amount of radiation may escape. If the truck or train is involved in an accident, there is a risk that the packages may be damaged and radioactive material released. Finally, there is the possibility of theft or sabotage.

The people who receive the most radiation during the course of normal transport are the handlers, truck crews, people in passenger air terminals, and warehousemen, in that order. 11/

People in vehicles, people in buildings, and pedestrians receive less. A surveillance program conducted in ten states found that individuals handling radioactive shipments were exposed to radiation doses of up to 2480 millirems per year which are considerably higher than the "maximum permissible dose" of radiation for the general public -- 500 millirems per year. There was also a significant amount of radiation in and around the transporting vehicles and in baggage handling depots. 12/

Human error is frequently to blame in incidents where radiation is released from a package in transport. A study of 153 "incidents" involving radioactive materials being transported through urban areas found that 90% of the incidents involved errors in packaging, handling, or stowing. Materials were improperly packed; packages were improperly closed or sealed. Packages were dropped or punctured during handling. Cargoes were improperly loaded onto vehicles so that they fell off or were damaged by other freight.13/ An Atomic Energy Commission survey in 1972 noted that human error could result in improperly closed containers and estimated that perhaps one in ten of those leaking containers is detected and reported.14/

Over the past 25 years, there have been about 350 reported vehicle accidents involving transportation of radioactive materials. The majority of the accidents, like the majority of the shipments, involved materials for medical or industrial use. Overall, about one-third of the accidents caused radioactive material to be released.15/

So far, no major disaster has occurred involving the shipment of materials to or from a nuclear reactor. The chance of such an accident occurring, however, is increasing with the increased transportation of these materials. According to the Department of Energy, approximately 15 truck and rail accidents per year involving nuclear materials can be expected when there are 200 reactors in the United States. One accident every five years would be "severe." 16/

It is not possible to predict the consequences of a severe accident. This would depend on what was being shipped, the circumstances of the accident, and the population density of the surrounding area. The greatest danger is thought to be from shipments of spent fuel.17/ One study estimates that a major release of spent fuel in an urban area could cost up to $700 million in decontamination and evacuation costs, and lost income. Such an accident could cause thousands of latent cancers as well as a large number of other health effects.18/ As in any other accident involving nuclear materials, a transportation disaster could contaminate a large area with radioactivity, which would be absorbed into the soil and enter the food chain and drinking water supplies.

The risks involved in transportation are compounded by the threat of terrorist activities. Some federal authorities have surmised that the transportation containers are so strong that they cannot be blown apart except with an impractically large quantity of explosives. It is theoretically possible to bore a hole through the casks, in which case a fraction of the radioactive material would be released. 19/

At the moment, theft is probably a greater threat than sabotage. Every year, a certain number of radioactive packages disappear in transit; most of these are found later. Nuclear materials such as uranium and plutonium are extremely valuable, and will be in increasing demand as nuclear technology spreads; it is possible to speculate on the growth of a worldwide black market in nuclear fuels. 20/ Furthermore, the government transports weapon-grade fuels (Special Nuclear Materials) by the same method as other nuclear shipments. Only about twenty pounds of plutonium are required to make a bomb.

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Atomic Energy Commission Estimates of Consequences of Maximum Credible Nuclear Power Plant Accidents

Since the first projections were made in the 1950s, estimates of the number of deaths and injuries from a major accident in a nuclear reactor have been continually revised upward. In 1957, the Atomic Energy Commission (AEC) had the Brookhaven National Laboratory conduct a study of the probable consequences of a major accident for a 100-200 megawatt reactor, the size being built at the time.1/ The study postulated an accident occurring at the end of the 180 day fuel cycle, when the reactor would contain the maximum amount of radioactive material. The results of the study have become famous. If the reactor was located 30 miles from a major city and if 50 percent of all fission products in the reactor escaped from the containment dome, under certain temperature conditions up to 3,400 people would be killed, 43,000 would be injured, up to 150,000 square miles of land could be contaminated, and property damage could range from up to $7 billion (depending on the extent of land contamination).

The Brookhaven report did not calculate the number of radiation induced latent cancers or birth defects. Nor did it fully assess the costs of a clean-up operation. But it did attempt to calculate the restrictions which would have to be placed on farming and land-use in the contaminated area. In the most contaminated area, people would be evacuated and could not return to their homes for an "indefinite" period of time, at least one year. In the intermediate range, people would be evacuated temporarily, but farming would have to be suspended for an indefinite period of time. In the least contaminated area, standing crops would have to be destroyed and farming might be suspended for one year. The report stressed that the effect on farming would depend on the level of strontium-90 in the radioactive fallout. This in turn depends on the number of days the core has been irradiated--that is, how many days the fuel has been "burned" in the reactor--when the accident occurs. Strontium-90 would accumulate in the top 2½ inches of soil and would remain there indefinitely, contaminating the milk of dairy cattle. Radioactive material washed into the soil by rain would also be absorbed by plants. The report concluded that while little was known about living in an environment contaminated by radioactivity, even low levels of contamination would cause serious problems for farming, particularly dairy farming.

The Brookhaven Report was originally commissioned because the U. S. Congress was about to consider the question of federal insurance for nuclear power plants and wanted an idea of the costs of a major accident. After the report was released, the

Price-Anderson Indemnity Act was passed. The Act placed a ceiling of $560 million on public liability for a nuclear accident, of which $500 million was to be paid by the federal government---that is, by the taxpayer.

In 1964, when Congress was considering an extension of the Price-Anderson Act, the Joint Committee on Atomic Energy requested the Atomic Energy Commission to re-examine and update the Brookhaven Report. This study was terminated while still in draft form and the findings were kept secret until 1973, the year when they were released in response to a Freedom of Information Act request. The 1965 study considered a different kind of accident from the ones described in the original Brookhaven Report. This reflected changes in reactor size, siting and technology since the original report was made. The updated study was based on a reactor, six times larger than the one in the Brookhaven Report, with a fuel cycle of 1000 days. Unlike a small reactor, a 1000 megawatt reactor will not cool off by itself even if it is shut down; it will continue to generate heat. Therefore, a system of artificial cooling must be used.2/ This creates the possibility of a new kind of accident - the failure of the cooling system.

The 1965 study described an accident in which the normal cooling system is blocked and the emergency core cooling system also fails to function. This results in the melting of 95% of the fuel and a meltdown through the containment building within six hours.3/ Once the containment dome is breached, some or all of the radioactive contents of the reactor are released in the form of a plume-shaped cloud. The radioactive material in this cloud then drifts downwind, gradually settling to the ground. The extent of the contaminated area depends on a number of factors, including weather conditions, the size of the particles in the cloud, and the level of radioactive materials in the reactor when the accident occurred.

The longer fuel cycle in the larger reactors means that correspondingly more radioactive products, such as Strontium-90, build up in the core. In addition, modern reactors are being sited increasingly close to population centers. Taking these factors into account, the 1965 study suggested fatalities on the order of 45,000, contamination of an area "the size of Pennsylvania," and damages amounting to approximately $17 billion dollars.

In commenting on the findings of the 1965 study, the Atomic Energy Commission insisted on the reliability of reactor safety systems. They stated that the possibility of a major loss-of-coolant accident was "highly unlikely," and that the consequences of such an accident would actually be "many orders of magnitude less than those calculated in the 1965 study." 4/

Since then, however, the possibility of a loss-of-coolant accident has become a major focus of the debate over nuclear safety. Such an accident could begin with the rupture of one of the cooling pipes. A 1973 Atomic Energy Commission report estimates that a major pipe rupture could occur as frequently as once in 1000 reactor years.5/ When the United States has 200 reactors (the number presently planned, operating, or under construction) this would be one rupture every five years. When the country has 500 reactors, this would be one rupture every other year.

In the event of a pipe rupture and consequent loss of cooling capacity, safety would depend on the emergency core cooling system (ECCS). The reliability of this mechanism has been questioned by scientists inside and outside of the nuclear industry and the Atomic Energy Commission. In 1972, following the failure of some important safety tests, the Atomic Energy Commission held hearings on the ECCS. Evidence and testimony at the hearings revealed that nuclear scientists at the Oak Ridge National Laboratory, as well as staff members at the Atomic Energy Commission, doubted the reliability of the emergency core cooling system and questioned whether it would always function properly in case of serious accidents.

Since the 1965 study was performed, reactor size has increased even further. Reactors up to 1200 megawatts are presently under construction with most sites including twin or triple reactors of about 1000 megawatts each. Release of fission products from such large plants could result in radiation deaths up to 100 miles away, according to one estimate.7/ Increasingly, plants are being sited in densely populated areas. The Indian Point plant, for example, is 25 miles from New York City. The Union of Concerned Scientists estimates that an accident at Indian Point, under conditions of temperature inversion, could result in 100,000 persons receiving lethal or near lethal doses of radiation. Radiation illness, latent cancers, genetic damage, and increased susceptibility to disease could occur at hundreds of miles from the site of an accident, given the size of modern plants.8/

While the failure of the ECCS is still a focus of research and concern, there is a growing realization that other, unforeseen occurrences can trigger accidents---accidents for which no safety system has been designed. Even if all mechanical failures could be avoided, there would still be the possibility of human error--and no one knows what form the next error will take. For example, no one foresaw that an electrician would check for air leaks with an ordinary candle at the Browns Ferry plant in 1975. The candle started a fire in the cable room which burned out about 1,600 control cables, many of which were connected to the operating reactor's safety systems. By chance, the fire spared certain wires which allowed operators to regain control of the plant. A more recent example of unforeseen occurrences is the hydrogen bubble which formed at Three Mile Island. The bubble posed the

the threat of blocking the cooling system and of a hydrogen explosion, which, if large enough, could have breached the containment dome.

References - AEC Estimates...

1. _Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants, WASH-740_, U. S. Atomic Energy Commission, March, 1957.

2. Clifford K. Beck, "Reactor Siting Criteria and Practice in the U. S." Address to the American Nuclear Society, Los Angeles, February, 1965. Cited in David Pesonen, "The Ticklish Statistics," _Nation_, October 18, 1965.

3. "Comments by AEC Regulatory Staff on the Principal Technical Assumptions in the 1965 Estimate of the Theoretical Consequences of a Major Reactor Accident." U. S. Atomic Energy Commission, June 19, 1973. Accompanies documents and working papers of 1965 update of WASH-740.

4. _Ibid_.

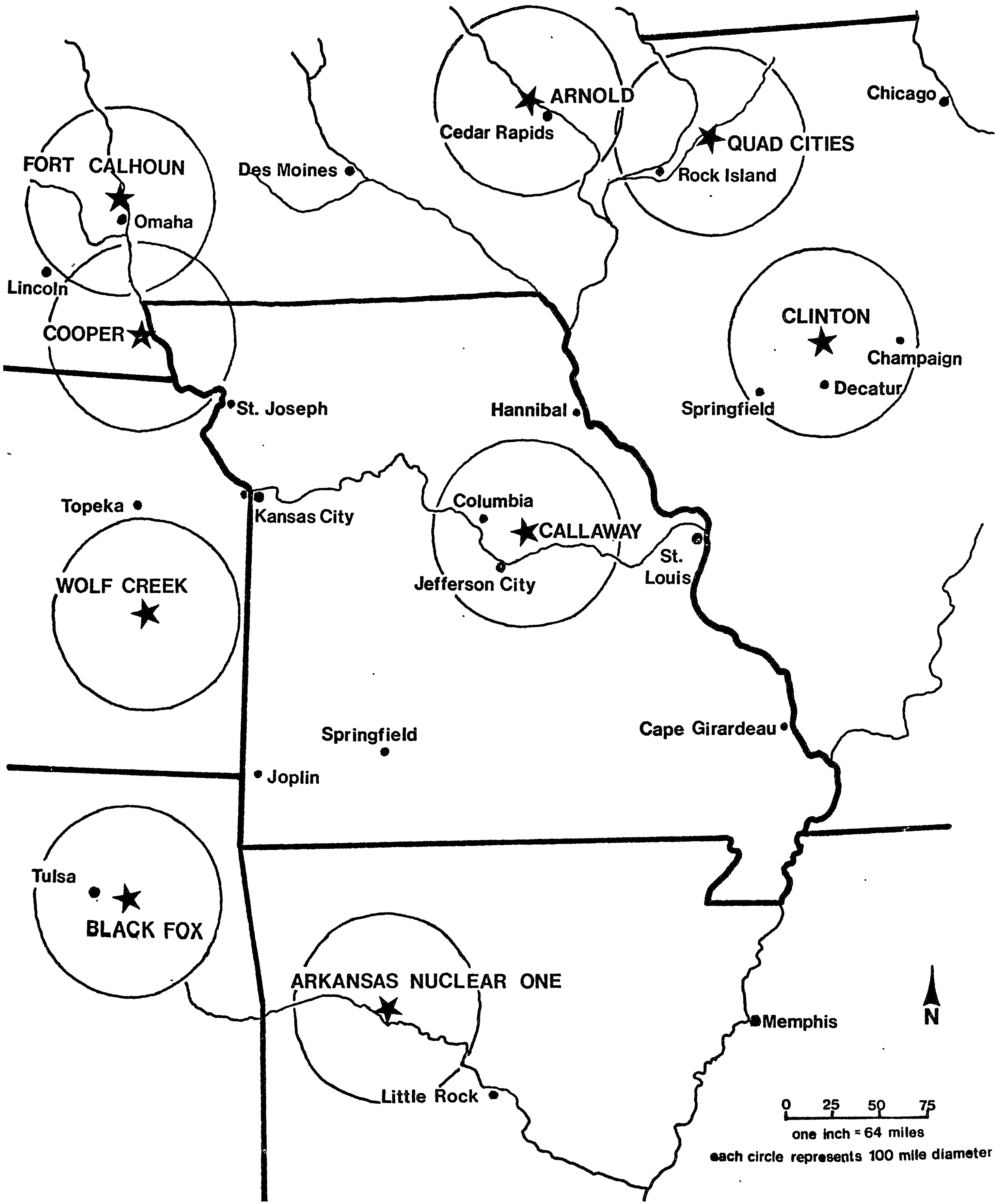
5. _The Safety of Nuclear Power Reactors and Related Facilities, WASH-1250_ U. S. Atomic Energy Commission, July 1973.

6. Emergency Core Cooling System (ECCS) Hearings. Atomic Energy Commission Docket RM-50-1.

7. Daniel F. Ford and Henry W. Kendall, "Catastrophic Nuclear Accidents", in Union of Concerned Scientists, _The Nuclear Fuel Cycle_. Friends of the Earth, 1974.

8. _Ibid_.

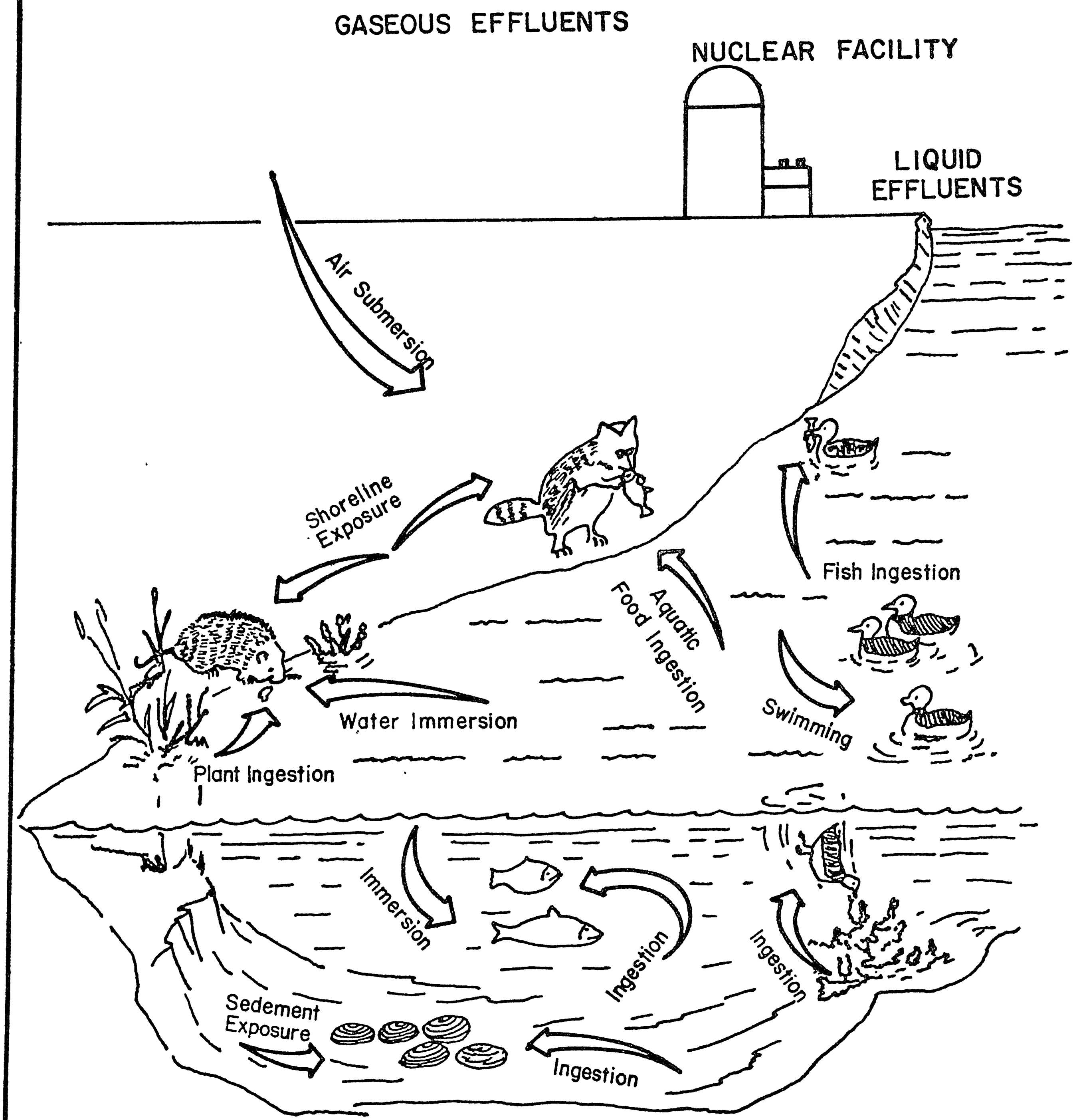
NUCLEAR POWER PLANTS
-OPERATING OR UNDER CONSTRUCTION



NUCLEAR POWER PLANTS IN MISSOURI AND SURROUNDING

STATES OPERATING OR UNDER CONSTRUCTION

Illinois	-	Clinton - Dewitt County
		Quad Cities - 20 miles Northeast of Moline
Arkansas	-	Arkansas Nuclear One - Russellville
Oklahoma	-	Black Fox - 3 miles Southwest of Inola
Kansas	-	Wolf Creek - 4 miles Northeast of Burlington
Nebraska	-	Cooper - 23 miles South of Nebraska City
		Ft. Calhoun - 19 miles North of Omaha
Iowa	-	Arnolds - 8 miles Northwest of Cedar Rapids
Missouri	-	Callaway - 10 miles Southeast of Fulton



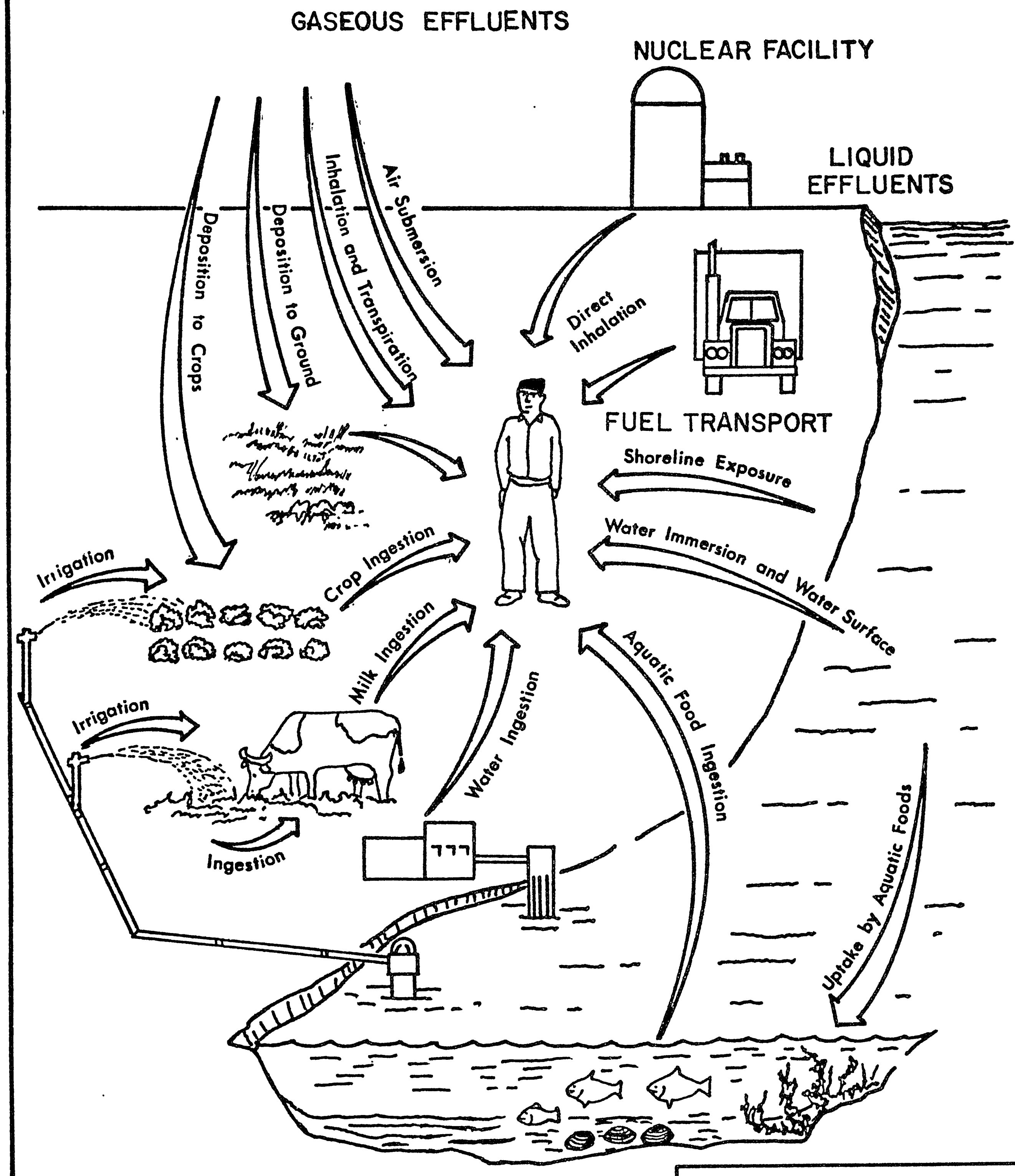
UNION ELECTRIC CO.
CALLAWAY PLANT
UNITS 1&2

POTENTIAL EXPOSURE PATHWAYS TO ORGANISMS OTHER THAN MAN

Figure 5.2-1

SOURCE:

Union Electric Company
ENVIRONMENTAL REPORT: CALLAWAY PLANT, UNITS 1 and 2



UNION ELECTRIC CO.
CALLAWAY PLANT
UNITS 1&2

POTENTIAL EXPOSURE PATHWAYS TO MAN

Figure 5.3-1

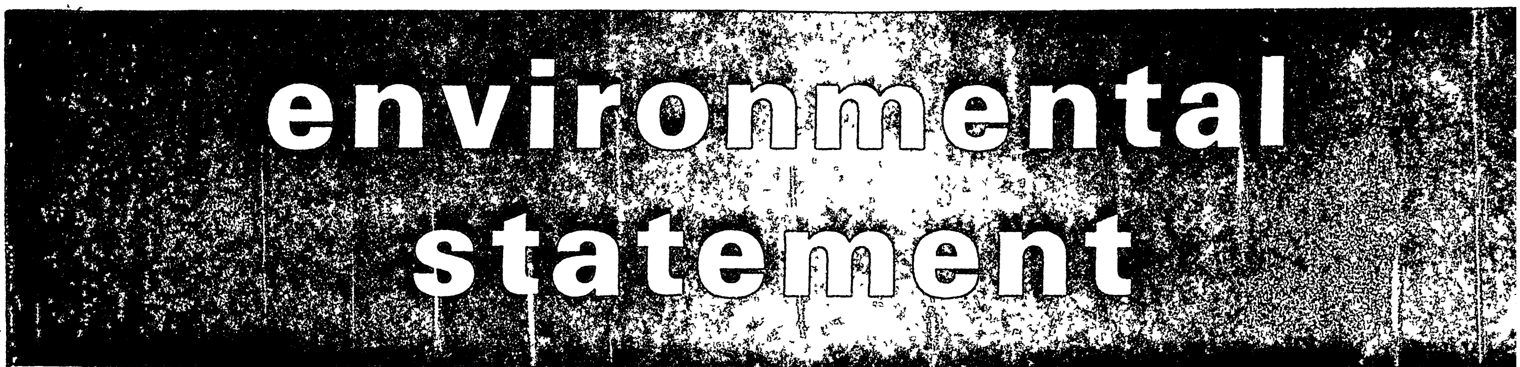
SOURCE:

Union Electric Company
ENVIRONMENTAL REPORT: CALLAWAY PLANT, UNITS 1 and 2

 APPENDIX F

NUREG-75/011

Final



related to the proposed

CALLAWAY PLANT
UNITS 1 and 2

UNION ELECTRIC COMPANY
Docket Nos. STN 50-483 and STN 50-486

Published: March 1975

UNITED STATES NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION

1. INTRODUCTION

1.1 THE PROPOSED PROJECT

In accordance with the Atomic Energy Act of 1954, as amended, and the Commission's regulations in Title 10, Code of Federal Regulations, the Union Electric Company applied for construction permits for two pressurized water nuclear reactors designed as the Callaway Plant Units 1 and 2 (Docket No. STN 50-483 and STN 50-486). Each unit is designed to operate at a thermal level of 3425 MWt and to produce a nominal net output of 1120 MWe. The net stretch output is expected to be 1160 MWe, deriving from a stretch thermal level of 3579 MWt (Ref 1, F6). The stretch output is considered in the assessments contained in this statement. The proposed plant is to be located on the applicant's property near Fulton, MO. Title to the plant site has been acquired except for portions of public roads which are proposed to be relocated. The property is in a rural region consisting of cropland, pasture, and forest. Construction is scheduled from mid-1975 to mid-1983.[2]

The plant's 90 cfs water requirement will be piped from the Missouri River, 5 mi S. Two natural draft cooling towers will be used. The flow rate of return water piped to the River will be about 23 cfs. The return water will consist largely of cooling tower blowdown and will have a temperature of 30° - 41°F above river water temperature in the winter and about 7° or 8°F above, in the summer.

Thirty miles of new transmission line corridor are proposed, along with widening 21 mi of existing corridor.

1.2 BACKGROUND

On April 30, 1974, the applicant tendered application to construct and operate the Callaway Plant. The application was docketed June 21, 1974. The applicant's schedule calls for operation of Unit 1 in October 1981 and Unit 2 in April 1983.

Title 10 CFR Part 51 requires that the Director of Regulation prepare a detailed statement of environmental considerations with respect to an application for constructing a nuclear power plant. Accordingly, this environmental statement related to constructing the Callaway Plant was prepared by the Directorate of Licensing (staff) of the U.S. Atomic Energy Commission.

In making its independent review the staff made use of information provided by the applicant. Major documents used were the applicant's Environmental Report (ER),[3] The Preliminary Safety Analysis Report (PSAR),[4] the PSAR Addendum,[5] and the Site Selection Study.[6] Independent calculations and sources of information also were used as a basis for assessing environmental impact. Some of the information was gained from visits by the staff to the plant site and surrounding areas in August 1974. Although data from all those sources were examined by the staff in making the assessment, only brief summaries of the most pertinent data are included in the statement. To minimize repetition, the staff has provided references to the sources of detailed information, much of which is found in the ER.

Copies of the statement and the ER are available for public inspection at the Commission's Public Document Room, 1717 H Street N.W., Washington, DC, at the Fulton City Library, 709 Market Street, Fulton, MO, and at the Olin Library of Washington University, Skinker and Lindell Boulevards, St. Louis.

1.3 STATUS OF REVIEWS AND APPROVALS

The applicant provided a status listing (Table 1.1) of environmentally-related permits, approvals, licenses, etc., required from Federal, State, regional, and local agencies in connection with the proposed project (Ref 3, Sec 12). The staff reviewed the listing and consulted with some of the appropriate agencies in an effort to identify any significant environmental issues of concern to the reviewing agencies. The staff also is following the hearings on this plant conducted by the Missouri Public Service Commission in order to take into account issues pertinent to the staff's independent environmental review.

TABLE 1.1 Permits and Licenses for the Plant (Ref 3, Sec 12)

Item	Agency or Jurisdiction	Permit Required For	Authority	Submission Schedule
1	Missouri Public Service Commission	Certificate of public convenience for the construction, operation and maintenance of Units 1 & 2	PL 393.170 RS Mo. 1969	April, 1974
2	U.S. Atomic Energy Commission	Construction permit for the construction of Units 1 & 2	Atomic Energy Act of 1954	April, 1974
3	Missouri State Highway Commission	Changes and alterations to roads	PL 228.160 RS Mo. 1969	4th Quarter, 1974
4	Callaway County Court	County road relocations	--	4th Quarter, 1974
5	Missouri Public Service Commission	Railroad crossing of public roadways	PL 389.640 RS Mo. 1969	4th Quarter, 1974
6	Missouri State Highway Commission	Hauling oversized and overweight loads	PL 304.200 RS Mo. 1969	2nd Quarter, 1975
7	U.S. Army Corps of Engineers	Construction permit for the construction of water intake and discharge facilities	River and Harbor Act of 1899, Sec. 10 (33 USC 407)	2nd Quarter, 1975
8	Missouri Department of Natural Resources	Operating permit for sewage plant and circulating water discharge and certification under the Water Pollution Control Act of 1972. Missouri Administers the National Pollutant Elimination System permit program for U.S. Environmental Protection Agency. An NPDES permit is required for point source discharges of area runoff (material storage runoff and construction runoff).	VAMS 204.051 (1972)	3rd Quarter, 1976
9	Federal Aviation Administration	Construction or alteration in transmission lines and cooling towers	49 USCA 1348	Pending determination of need
10	Missouri Public Service Commission	Certificate of public convenience for the installation and operation of transmission lines	PL 393.170 RS Mo. 1969	2nd Quarter, 1975
11	Missouri Department of of Social Services	Pollution control equipment construction and operation anc air pollution emission	VAMS 203.050, 203.075, 203.110 (1972)	2nd Quarter, 1975
12	Missouri Department of Social Services	Sanitary land fill sewage treatment plant	Chapter 192 RS Mo. 1969	2nd Quarter, 1975
13	Missouri Department of Social Services	Land fill	Chapter 192 RS Mo. 1969	2nd Quarter, 1975
14	Missouri Department of Social Services	Noise	None at present	Pending determination of need
15	U.S. Army Corps of Engineers	River dredging and fill, coffer dam construction	33 USCA 401	2nd Quarter, 1975
16	U.S. Atomic Energy Commission	Materials license to possess special nuclear materials prior to operating license	Code of Fed. Reg. 1967 Chapter 10, Section 30	Mid-1978
17	U.S. Atomic Energy Commission	By-product license to possess special nuclear materials prior to operating license	Code of Fed. Reg. 1967 Chapter 10, Section 30	Mid-1978
18	U.S. Atomic Energy Commission	Transportation of radioactive materials	Code of Fed. Reg. Title 10 Chapter 1, Part 71	Mid-1978
19	U.S. Atomic Energy Commission	Operating permit for operation of Units 1 & 2	Atomic Energy Act, 1954	June, 1979
20	U.S. Army Corps of Engineers	Transmission line crossing of Gasconade River[7]		
21	Missouri Department of Natural Resources	Water quality certification	Section 401, FWPCA Amendments of 1972	Issuance required prior to limited work authorization by NRC

REFERENCES FOR SECTION 1

1. Union Electric Company, Callaway Plant, Units 1 and 2 Environmental Report, Rev 1, Oct 15, 1974.

2. Letter to Edson G. Case, AEC, from John K. Bryan, UEC, Sept 13, 1974.

3. Union Electric Company, Callaway Plant Units 1 and 2 Environmental Report, Vol I, II, and III, May 1974.

4. Kansas City Power and Light Company, Kansas City Gas and Electric Company, Northern States Power Company, Rochester Gas and Electric Company, Union Electric Company, Standardized Nuclear Unit Power Plant System, SNUPPS, Preliminary Safety Analysis Report, Vol 1, 2, 3, 4 and 5.

5. Union Electric Company, Callaway Plant Units 1 and 2 Addendum Standardized Nuclear Unit Power Plant System, SNUPPS, Preliminary Safety Analysis Report, Vol 1, 2, and 3, June 1974.

6. Union Electric Company, Site Selection Study Phase I and Phase II, Vol 1 and 2, by Dames and Moore, May 1974.

7. Letter to G. W. Knighton, AEC, from J. K. Bryan, UEC, January 6, 1975.

2. THE SITE

2.1 GENERAL

The Callaway Plant site is located in Callaway County, Missouri, about 10 mi SE of Fulton and about 5 mi N of the Missouri River. The site lies on a plateau over 300 ft above the River. The mid-point of the plant's two adjacent reactors is located at 38° 45' 42.3" N latitude and 91° 74' 52.4" W longitude. The site is about 80 mi W of metropolitan St. Louis. Plant buildings and intermediate spaces will occupy about 200 acres of plant site. The plant site, the peripheral area, and the plant corridor area total 6600 acres owned or under negotiation for purchase by the applicant. The site location is shown in Figure 2.1, and by photograph in Figure 2.2 (Ref 1, Fig 2.1-1).[2]

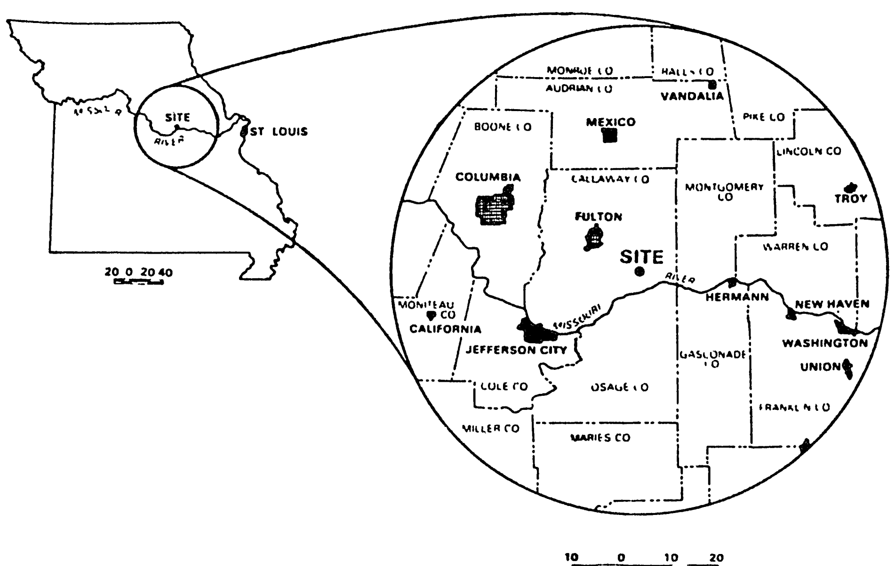
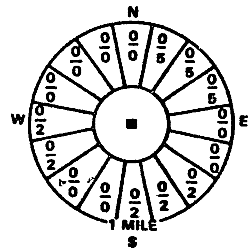


FIGURE 2.1 Callaway Site Location

Within 5 mi of the site, about 1% of the land is built up, consisting of the Readsville, Steedman and Portland areas (Figure 2.3). There are no schools, other institutions, and manufacturing. About 40% of the land is in crops or pasture, mainly for livestock production. Dairy and poultry production are relatively small. About 60% of the land consists of hardwood forest dominated by oak (Ref 1, Figure 2.2-6). Forest products are at times harvested commercially. The principal recreational activity is hunting for deer and small game. There are no wildlife management areas within 5 mi, although the Cedar Creek Management (recreation) Area, 5 Mi W, is under federal wildlife and forest management. By 1975, 2000 campsites are expected to have been sold at Lost Canyon Lake, a forested area about 2.2 mi N. The Missouri Kansas Texas (MKT) Railroad and Missouri Route 94 run 3.5 and 3.7 mi S of the site. Several lettered state roads run through the area.

Within 10 mi of the site, the same rural dominance continues, with no significant alteration expected in the near future. School enrollment consists of about 600 students at Mokane and 500 at Chamois. Health facilities are located at Mokane and Fulton. A sand and gravel quarry is located 7.5 mi SE at Mokane. An 8 inch petroleum products pipeline lies 8 mi N. Several recreational areas are present. The most significant are Riverside Park and Chamois Access Park, both 6 mi S at Chamois, with yearly attendance of 5000 to 10,000 people. There are no military facilities or airports within 10 mi (Ref 1, pp 2.2-6 to 2.2-10).



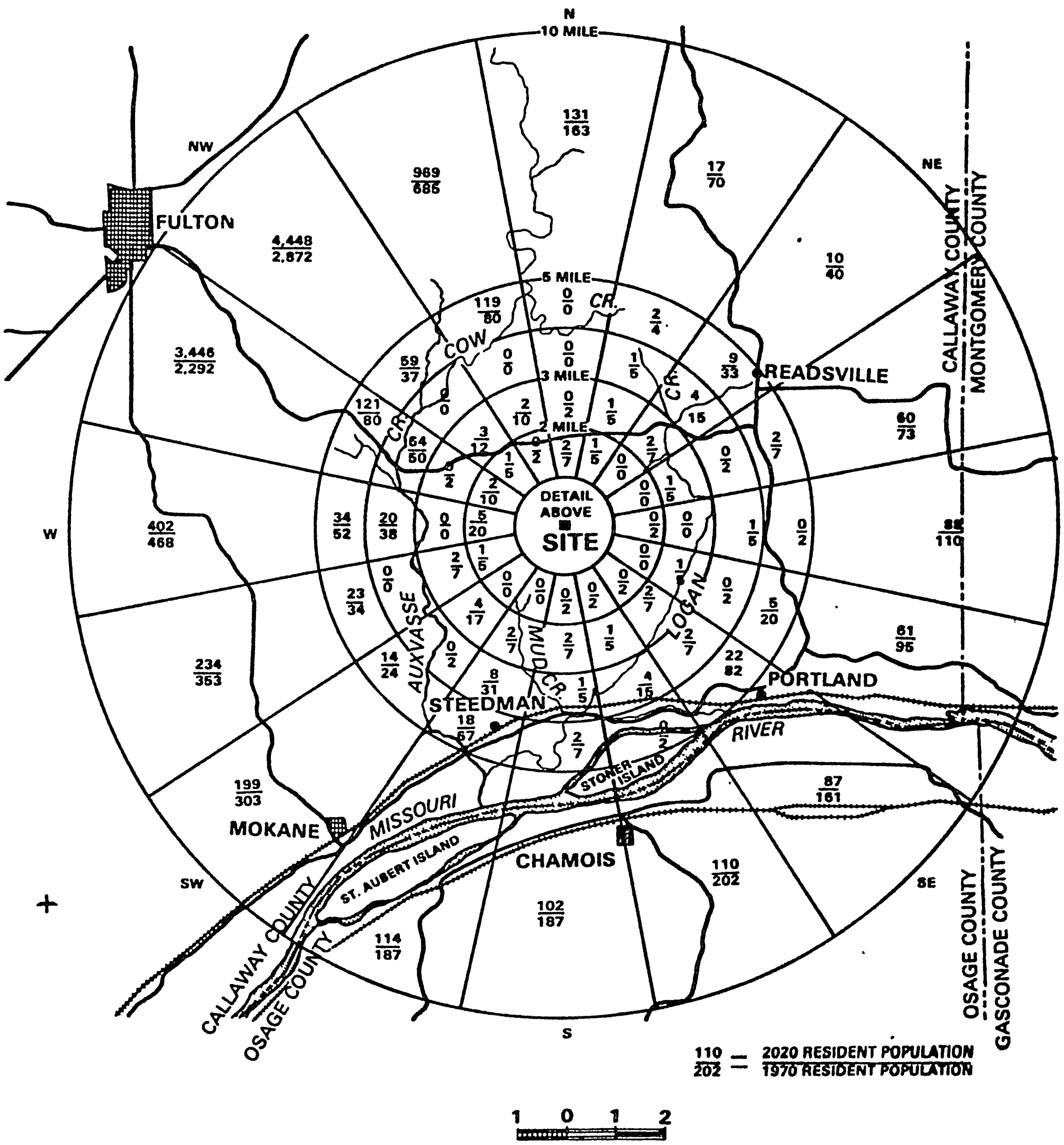


FIGURE 2.3 Population Distribution for 1970 and 2020, Within a 10-mile Radius of the Callaway Site

Wells within 5 mi of the site serve only individuals. The 46 wells and 10 enclosed springs are 10 to 500 ft deep and sustain a total withdrawal of about 20,000 gpd. About 80 wells provide supplies to municipalities and public water districts, within 50 mi and N of the River (Ref 1, pp 2.2-10, 11). Potable supplies are not obtained from surface water in the area; the first downstream domestic use is 50 mi away, at Washington. Some surface water is used for livestock and irrigation. Commercial fishing on the River results in an annual catch of nearly 5000 lb for Callaway County. Sport fishing occurs on numerous streams within 5 mi. In 1971, commercial barge traffic on the River consisted of over 36,000 passengers and about 1,300,000 ton-mi of materials (Ref 1, pp 2.2-6 to 2.2-12).

2.2 REGIONAL DEMOGRAPHY

The closest population centers are Jefferson City, 25 mi WSW, and Columbia, 30 mi WNW from the site. In 1970, the 10 mi radial area had a population of 9189, and the 50 mi area, 305,411, figures indicating the region's rural character. The corresponding population totals for 1980 are estimated to be 9529 and 348,674 (Ref 1, Table 2.2-2 and 2.2-3). A population growth of 21% is indicated over the next 50 yrs for the area within 50 mi of the plant. Population distributions in 1970 and 2020 estimates are shown in Figure 2.3 and 2.4 (Ref 1, p. 2.2-2).

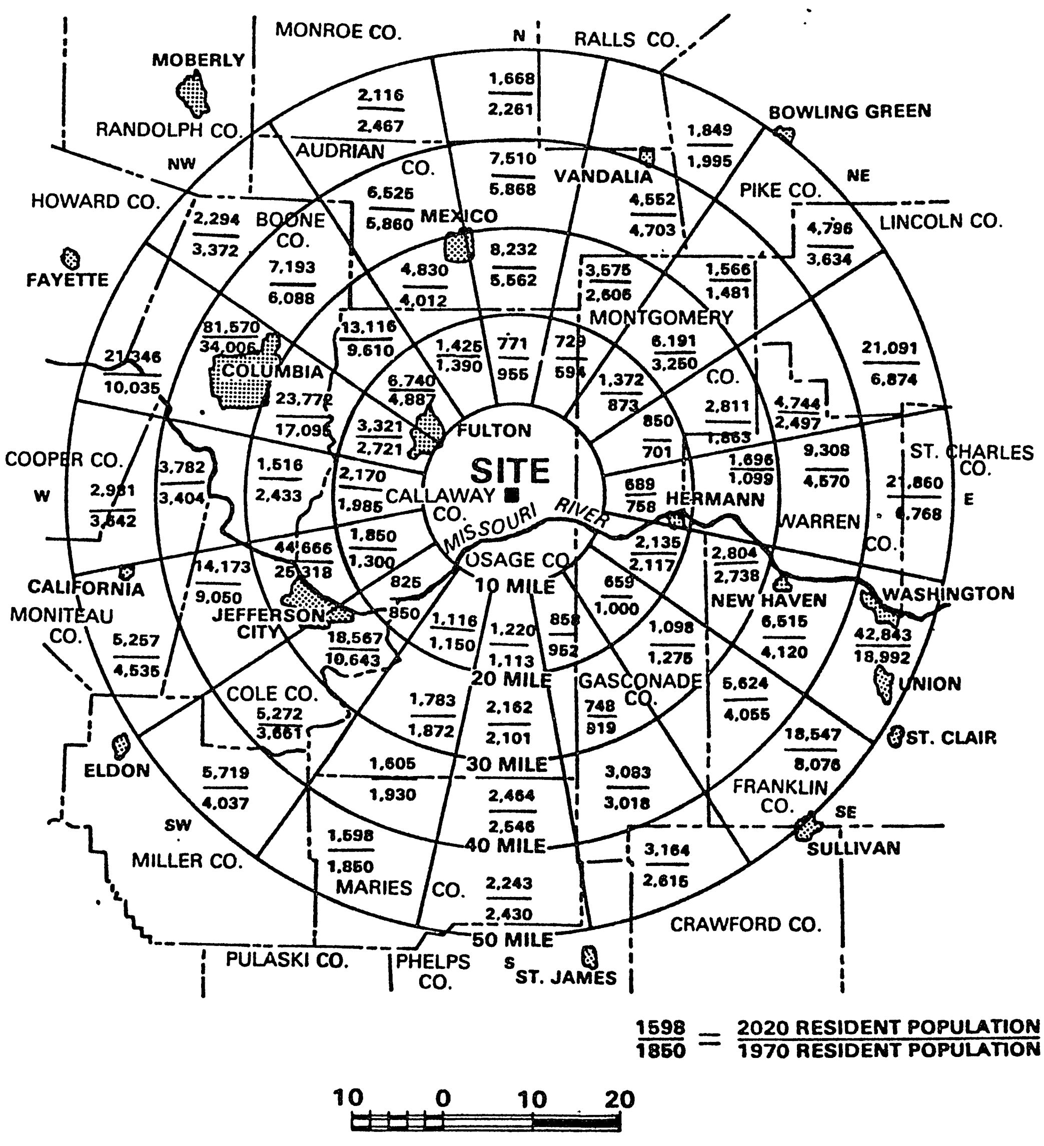


FIGURE 2.4 Population Distribution for 1970 and 2020, Within 50 Miles of the Site

RESIDENT POPULATION DISTRIBUTION BY RADIAL DISTANCE FROM

CALLAWAY REACTOR IN MILES

Sector	Year	10 Mile Total	10-20	20-30	30-40	40-50	50 Mile Total
Grand	1970	9189	23,373	92,405	96,873	83,571	305,411
Total	1980	9529	24,187	104,150	110,041	100,746	348,674
	1990	10,493	27,084	113,927	120,868	118,985	391,374
	2000	10,757	27,144	122,143	134,391	130,987	425,435
	2010	11,028	27,177	130,791	140,074	145,511	465,591
	2020	11,116	26,739	137,574	165,494	160,011	500,946

Note: Discrepancies in grand total figures due to rounding error.

Source of Data: U.S. Bureau of Census, 1970
Source of Table: Dames & Moore, 1973

Assuming a 5 gpm leak rate at main steam activity (0.001 secondary coolant concentration), the staff calculated a release of approximately 0.05 Ci/yr/reactor, excluding tritium, from that source. Detergent wastes generated from laundry and decontamination operations normally will be released to the circulating water discharge. If the radioactivity level is above a predetermined level, the wastes will be processed through a reverse osmosis unit and, if necessary, the LWPS. The staff assumed all waste will be processed through the reverse osmosis unit only prior to release. Based on our assumption of 450 gpd of detergent waste at 10^4 μCi/cc and a DF of 30 for the reverse osmosis unit, the staff calculated a release of 0.002 ci/yr/reactor, excluding tritium, from that source.

3.5.1.4 Steam Generator Blowdown

Blowdown from the steam generators normally will be returned directly to the condenser, but there will be provisions to discharge the blowdown to the environment without processing. However, if the radioactivity level in the material being released to the environment exceeds a predetermined level, flow automatically will be terminated by one of two radiation monitor controlled valves. The blowdown then will be processed through a system consisting of two mixed bed demineralizers and either recycled to the condenser or released to the environment. The staff assumed the blowdown rate will be approximately 18 gpm (0.06% of the main steam flow rate) at secondary coolant activity and that 10% of the flow will be released to the environment after processing. Based on those assumptions about 0.04 Ci/yr/reactor, excluding tritium, will be released from that source.

3.5.1.5 Liquid Waste Summary

In evaluating the liquid waste systems, the staff calculated the releases of radioactive materials in liquid waste to be approximately 0.29 Ci/yr/reactor, excluding tritium and dissolved gases. The release was normalized to 0.6 Ci/yr/reactor to account for equipment downtime and anticipated operational occurrences.[6] The tritium release was calculated to be approximately 350 Ci/yr/reactor. The applicant estimated the liquid release to be approximately 0.08 Ci/yr/reactor, excluding tritium and dissolved gases, and 100 Ci/yr/reactor for tritium (Table 3.5).

TABLE 3.5 Liquid Source Term

Nuclide	Ci/yr/reactor	Nuclide	Ci/yr/reactor
^{24}Na	0.00002	^{99}Mo	0.0092
^{32}P	0.00001	^{99m}Tc	0.0087
^{33}P	0.00004	^{127m}Te	0.00005
^{51}Cr	0.00017	^{127}Te	0.00006
^{54}Mn	0.00007	^{129m}Te	0.00024
^{56}Mn	0.00027	^{129}Te	0.00015
^{55}Fe	0.00017	^{130}I	0.00055
^{59}Fe	0.00010	^{131m}Te	0.00012
^{58}Co	0.0018	^{131}Te	0.00002
^{60}Co	0.00050	^{131}I	0.32
^{63}Ni	0.00002	^{132}Te	0.0022
^{92}Nb	0.00003	^{132}I	0.015
^{117m}Sn	0.00001	^{133}I	0.14
^{187}W	0.00012	^{134}I	0.0004
^{239}Np	0.00004	^{134m}Cs	0.00012
^{82}Br	0.00013	^{134}Cs	0.03
^{83}Br	0.00019	^{135}I	0.025
^{86}Rb	0.00008	^{136}Cs	0.01
^{88}Rb	0.00133	^{137}Cs	0.02
^{89}Rb	0.0007	^{137m}Ba	0.01
^{89}Sr	0.00006	^{138}Cs	0.0001
^{91}Sr	0.00001	^{139}Cs	0.0003
^{91m}Y	0.00010	^{139}Ba	0.00002
^{91}Y	0.00057	^{140}Ba	0.00006
^{92}Y	0.00002	^{140}La	0.00006
^{95}Zr	0.00001	^{141}Ce	0.00001
^{95}Nb	0.00001	Others	0.00012
		Total (except ^{3}H)	0.6 Ci
		^{3}H	350 Ci

After evaluation of liquid radwaste releases, the staff calculated that the whole body and critical organ doses will be less than 5 mrem/yr at or beyond the site boundary, and that the proposed systems will be capable of limiting the release of radioactive materials in liquid effluents to less than 5 Ci/yr/reactor. The staff finds the proposed liquid radwaste sytem capable of reducing effluents to as low as practicable levels in accordance with 10 CFR Part 20 and 10 CFR Part 50. The staff concludes that the proposed liquid radwaste system will be acceptable.

3.5.2 Gaseous Waste

The principal source of radioactive gaseous wastes will be gases stripped from the primary coolant in the BRS. Additional sources of gaseous wastes will be main condenser air removal system offgases, ventilation exhausts from the auxiliary fuel and radwaste buildings, and gases collected in the reactor containment building. The principal system for treating gaseous wastes will be the gaseous waste processing system (GWPS). The GWPS will collect and store gases stripped from the primary coolant and gases vented from tanks and systems containing radioactive fission gases. The GWPS will consist of two compressors, two catalytic recombiners and eight gas decay tanks. Ventilation air from the fuel, auxiliary and radwaste buildings and offgases from the main condenser air ejectors will be processed through charcoal adsorbers prior to release. The reactor containment atmosphere will be recirculated through HEPA filters and charcoal adsorbers prior to release. Ventilation air from the turbine building will be released without treatment. Ventilation air from the containment, auxiliary and fuel buildings and gaseous wastes from the condenser air removal system will be exhausted through the unit vent atop the containment building. Ventilation air from the radwaste and turbine buildings will be exhausted through the radwaste and turbine building roof vents, respectively. The gaseous waste and ventilation treatment systems are shown schematically in Figure 3.11.

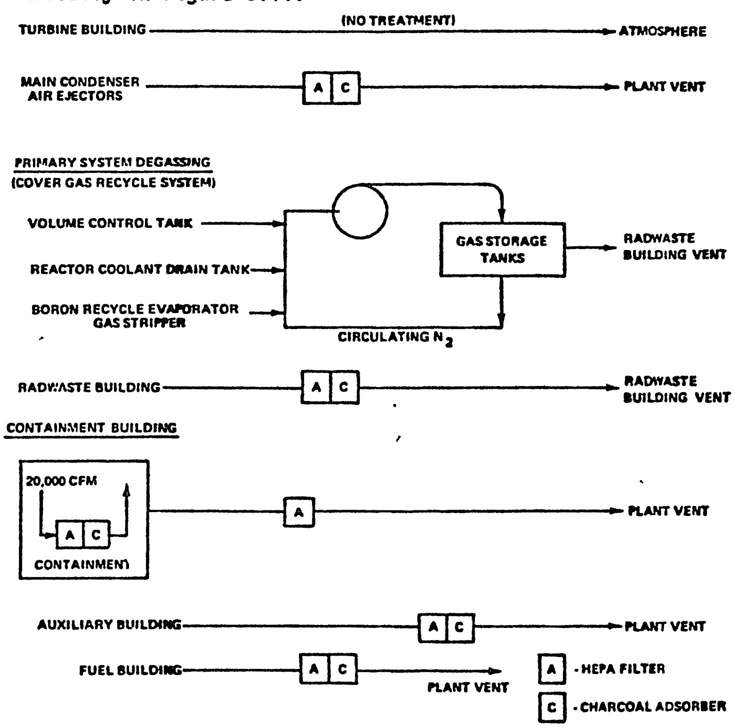


FIGURE 3.11 Gaseous Waste Treatment Systems

3.5.2.1 Gaseous Waste Processing System (GWPS)

The GWPS will be designed to collect and process gases stripped from the primary coolant along with cover gases from miscellaneous tanks. Gaseous inputs will include a continuous 0.7 scfm hydrogen purge of the CVCS volume control tank and smaller quantities of radioactive gas from the boron recycle evaporator, reactor coolant drain tank and the recycle holdup tanks. Input gases will be processed in a closed loop containing two waste gas compressors, two catalytic hydrogen recombiners and eight 600 ft^3 gas decay tanks (six for normal operation and two for startup and shutdown). The system will be designed for continuous recycle of radioactive gases; however the staff's evaluation assumed the radioactive gases will be released to the atmosphere after a 90 day holdup in the system. On that basis the staff calculated the GWPS releases to be approximately 990 Ci/yr/reactor for noble gases and negligible ($<10^{-4}$ ci/yr/reactor) for ^{131}I.

3.5.2.2 Containment Ventilation System

Radioactive gases will be released inside the reactor containment when primary system components are opened or when leakage occurs from the primary system. The gaseous activity will be sealed within the containment during normal operation, but will be released during containment purges. Prior to purging the containment, the containment atmosphere will be recirculated through the containment atmospheric control system (CACS) at about 20,000 cfm. The CACS will consist of two parallel trains, each containing HEPA filters and an activated charcoal adsorber. Purge effluent

will be released from the plant vent after passing through HEPA filters and being monitored for radioactivity. The staff calculated the containment airborne activity based on 240 lbs/day primary coolant leakage to the containment and a partition factor of 0.1 for radioiodine. Assuming four purges of the containment per year, the staff calculated releases from the containment to be approximately 22 Ci/yr/reactor for noble gases and negligible for ^{131}I. The figures were essentially the same as those calculated by the applicant.

3.5.2.3 Ventilation Systems for Other Buildings

Radioactive material will be introduced into the plant atmosphere due to leakage from equipment processing or holding radioactive materials. Ventilation air from the auxiliary and fuel buildings will be processed through HEPA and charcoal filters, monitored for radioactivity and released through the plant vent. Ventilation air from the radwaste building will be processed in the same manner and released through the radwaste building roof vent. Ventilation air from the turbine building will be monitored for radioactivity and released without treatment. The staff estimates that 160 lbs/day of primary coolant will leak to the auxiliary and radwaste buildings. Since the letdown heat exchangers will be located inside the reactor containment, the staff assumed all leakage will be cold and applied a partition factor of 0.001 for radioiodine. On that basis the staff calculated the auxiliary and radwaste building releases to be approximately 180 Ci/yr/reactor for noble gases and 0.0037 Ci/yr/reactor for ^{131}I. The applicant calculated the auxiliary and radwaste building releases to be approximately 1270 Ci/yr/reactor for noble gases and 0.002 Ci/yr/reactor for ^{131}I. The difference between the estimates for noble gas release is due principally to the applicant's assumption that the noble gases in the GWPS will be continually recycled and that 100 scfm/yr will leak from the GWPS into the radwaste building (Subsec 3.5.2.1).

The staff estimated that 1700 lbs/hr of steam will leak to the turbine building atmosphere and all noble gases and radioiodine released with the steam will remain airborne. On that basis the staff calculated the turbine building vent release to be less than 1 Ci/yr/reactor for noble gases and 0.045 Ci/yr/reactor for ^{131}I. The applicant calculated the turbine building releases to be negligible for noble gases and ^{131}I.

3.5.2.4 Steam Releases to the Atmosphere

The turbine bypass capacity to the condenser will be approximately 40%. The staff's analysis indicates that steam releases to the environment due to turbine trips and low power physics testing will have a negligible effect on the staff's calculated source terms.

3.5.2.5 Main Condenser Offgas Releases

Offgas from the main condenser air ejectors will contain radioactive gases resulting from primary to secondary system leakage. Iodine will be partitioned between the steam and water in the steam generators and between the condensing and noncondensing phases in the main condenser. Main condenser offgas will be processed through a charcoal adsorber prior to release. The staff considered 110 lb/day primary to secondary system leakage, partition factors for radioiodine of 0.01 anddn 0.0005 in the steam generator and main condenser, respectively, and an iodine decontamination factor of 10 for the charcoal adsorber on the offgas line. On that basis the staff calculated the main condenser offgas releases to be approximately 177 Ci/yr/reactor for noble gases and 0.02 Ci/yr/reactor for ^{131}I. The applicant calculated the releases from the main condenser to be approximately 155 Ci/yr/reactor for noble gases and 0.004 Ci/yr/reactor for ^{131}I.

3.5.2.6 Gaseous Waste Summary

In evaluating the gaseous waste treatment systems, the staff calculated the total releases of radioactive materials in gaseous waste to be approximately 1400 Ci/yr/reactor for noble gases and 0.04 Ci/yr/reactor for ^{131}I. The applicant estimated the gaseous releases to be approximately 1500 Ci/yr/reactor for noble gases and 0.05 Ci/yr/reactor for ^{131}I (Table 3.6).

After evaluation of the applicant's proposed gaseous radwaste treatment system, the staff calculated that the annual air dose due to gamma radiation at or beyond the site boundary will not exceed 10 millirads, the annual air dose due to beta radiation at of or beyond the site boundary will not exceed 20 millirads, the annual dose to an individual by all pathways as evaluated in Subsection 5.4 will not exceed 15 mrems and the annual total quantity of ^{131}I released will not exceed 1 Ci/reactor. The staff finds the proposed gaseous radwaste system capable of reducing effluents to as low as practicable levels in accordance with 10 CFR Part 20 and 10 CFR Part 50 and, therefore, the gaseous radwaste system to be acceptable.

3.5.3 Solid Waste

The solid waste management system (SWMS) will be designed to process two general types of solid waste, "wet" waste which requires solidification and packaging and "dry" solid waste which requires packaging only. "Wet" solid waste will consist mainly of spent filter cartridges, demineralizer

TABLE 3.6 Gaseous Source Term

(Ci/yr/reactor)

	Decay Tanks	Building Ventilation Containment	Building Ventilation Auxiliary	Turbine	Air Ejector	Total
^{83m}Kr	a	a	2	a	2	4
^{85m}Kr	a	a	7	a	7	14
^{85}Kr	972	a	a	a	5	977
^{87}Kr	a	a	5	a	5	10
^{88}Kr	a	a	13	a	14	27
^{89}Kr	a	a	a	a	a	a
^{131m}Xe	12	3	a	a	a	15
^{133m}Xe	a	1	3	a	3	7
^{133}Xe	5	22	130	a	132	289
^{135m}Xe	a	a	1	a	1	2
^{135}Xe	a	a	15	a	2	17
^{137}Xe	a	a	a	a	a	a
^{138}Xe	a	a	4	a	4	8
^{131}I	a	0.008	0.008	0.03	0.01	0.052
^{133}I	a	0.006	0.01	0.02	0.008	0.044

a Less than 1 Ci/yr noble gases, less than 10^{-4} Ci/yr iodines

resins and evaporator and RO unit concentrates and will contain radioactive materials removed from liquid streams during processing. "Dry" solid waste will consist mainly of low activity ventilation air filters, contaminated clothing, paper, and miscellaneous items such as laboratory glassware and tools. Miscellaneous solid wastes, such as irradiated primary system components, will be handled on a case-by-case basis based on their size and activity. The principal sources of spent demineralizer resins will be four 30 ft^3 CVCS evaporator condensate demineralizers, two 30 ft^3 LWPS demineralizers, and four 75 ft^3 steam generator blowdown demineralizers. Spent resins from the demineralizers will be collected in the 4000 gal SGB spent resin storage tank and the 2600 gal LWPS spent resin storage tank, sluiced to a solidification holdup tank for dewatering, mixed with a solidification agent and catalyst and solidified in 55 gallon drums.

Concentrated wastes from the two 35 gpm LWPS evaporators and the 15 gpm CVCS boric acid evaporator will be pumped from their respective concentration holdup tanks to the 750 gal solidification holdup tank. Concentrates from the solidification holdup tank and solidification agent will be pumped simultaneously to the shipping containers for solidification. A catalyst will be added in the shipping container.

Based on evaluations of PWRs with similar liquid waste systems, the staff determined that approximately 4500 ft^3/reactor of wet solid wastes will be generated annually, containing approximately 6000 Ci/reactor of radioactivity, principally ^{137}Cs and ^{134}Cs. The applicant estimated the wet solid wastes shipped offsite per reactor to be approximately 7400 ft^3/yr containing 9500 Ci of activity. Dry solid wastes will be packaged in 55-gal drums. Compressible wastes, eg., clothing and contaminated rags, will be compressed using a hydraulic baler. The staff estimates the dry solid wastes per reactor to be approximately 450 drums/yr containing a total of 5 Ci. The applicant estimated essentially the same.

Solid Waste Summary

Based on evaluation of the solid waste system the staff concludes that the system design will accommodate the wastes expected during normal operations including anticipated operational occurrences in accordance with existing AEC, local and Federal Regulations. The wastes will be packaged and shipped to a licensed burial site in accordance with AEC and Department of Transportation Regulations. Based on those findings, the staff concludes that the solid waste system will be acceptable.

3.6 CHEMICAL AND BIOCIDAL EFFLUENTS

Normal operation requires the use of certain cleaning agents and chemicals for 1) laboratory uses, 2) the production of high purity boiler feedwater, 3) prevention of scale formations in cooling towers, and 4) inhibiting residual biological growth in the condensers.

Chemicals expected to be discharged into the River are tabulated in Table 3.7 (Ref 3, E9). The ambient levels of the same chemicals in the River prior to discharge are also provided for comparison purposes.

TABLE 3.7 Estimated Release of Chemicals to the River (Ref 3, E9)

	lbs/year Added	Plant Source	Frequency of Discharge	Plant Discharge Concentration mg/ℓ	River Concentration Prior to Discharge mg/ℓ	River Concentration After Discharge mg/ℓ	River Concentration Increase %
Sulfate[a]	3,394,500	Blowdown	Continuous	1,079	260	262.30	0.87
Sulfate[b]	3,978,500	Demineralizer	4 hrs/day	1,598[b]	260	263.71	1.43
Sodium[a]	0	Blowdown	Continuous	246	65	65.52	0.80
Sodium[b]	1,675,350	Demineralizer	4 hrs/day	470	65	66.12	1.72
Phosphonates	1,733,750	Blowdown	Continuous	37.7	(g)	(g)	(g)
Copper	18,400	Blowdown	Continuous	0.52	0.031	0.03248	4.77
Nickel	2,040	Blowdown	Continuous	0.04	(g)	(g)	(g)
Chlorine	1,789[c]	Blowdown	4 hrs/day	0.23[c]	(g)	(g)	(g)
Dissolved Solids[a]	5,128,250	Blowdown	20 hrs/day	2,404	605	610	0.82
Dissolved Solids[a]	39,051,350[d]	Blowdown & Demineralizer	4 hrs/day	3,141	605	612	1.16
BOD	730[e]	Sanitary Sewage	Continuous	0.016	(g)	(g)	(g)
NH_3-N	365[e]	Sanitary Sewage	Continuous	0.008	(g)	(g)	(g)
Total SS[f]	138,103,590	--	--	3,003	772	780	1.03
Suspended Solids	137,226,860[h]	Water Treatment Plant	Continuous				
Polyelectrolyte	7[illegible],000	Water Treatment Plant	Continous				
Suspended Solids	730	Sewage	Continuous				

(a) Quantities are for operation during periods when there is no chemical waste from the demineralizer.

(b) Quantities are for operation during periods when there is chemical waste from the demineralizer regeneration.

(c) Maximum total residual chlorine (free plus combined) leaving discharge line during the circulating water chlorination periods.

(d) Instantaneous daily rate reflecting disposal of total daily regenerant waste in a 4 hour period.

(e) Based on normal operation after plant (two units) is completed.

(f) Total suspended solids includes contributions from process water treatment (SS in raw water and from polyelectrolyte additions) and residual suspended solids present in sewage treatment effluent.

(g) Unknown.

(h) Contained in makeup from the Missouri River.

3.6.1 Raw Water Treatment

The yearly average concentrations of suspended solids in the River is 320 mg/ℓ. The solids load entering the plant will be reduced by coagulating the suspended solids with 0.5 mg/ℓ of polyelectrolyte in raw water (200 lb/day of polyelectrolyte). The clarified water, expected to have a suspended solids content of 15 mg/ℓ, will then be pumped to the circulating and service water systems (Ref 1, p. 3.6-1).

The coagulated solids will be concentrated in the bottom of a clarifier and continuously drawn off for return to the River. The volume of makeup water required by the circulating and service water systems and the suspended solids concentration in river water both vary seasonally. The two factors will cause variations in the amount of water treatment sludge produced and the suspended solids concentration in the discharge to the River. Table 3.8 shows the expected seasonal variation in suspended solids to be discharged (Ref 3, E1). On the basis of those data, the average suspended solids concentration in the discharge is expected to be about 1500 mg/ℓ (Ref 3. E1). During unusually low flows, some material may settle out downstream of the discharge pipe; however, the average river velocity should keep most of the solids in suspension throughout the course of the River. Spring flooding and other high water should scour away any materials that build up during low-flow months, thus preventing any net buildup of sediments (Ref 3, E-2).

7. ENVIRONMENTAL EFFECTS OF POSTULATED ACCIDENTS

7.1 POSTULATED ACCIDENTS INVOLVING RADIOACTIVE MATERIALS

A high degree of protection against the occurrence of postulated accidents in the plant is provided through correct design, manufacture, operation, and the quality assurance program used to establish the necessary high integrity of the reactor system, as will be considered in the Commission's Safety Evaluation. Deviations that may occur will be handled by protective systems to place and hold the plant in a safe condition. Notwithstanding that, the conservative postulate is made that serious accidents might occur, even though they may be extremely unlikely; and engineered safety features are installed to mitigate the consequences of postulated events judged credible.

The probability of occurrence of accidents and the spectrum of their consequences to be considered from an environmental effects standpoint were analyzed using best estimates of probabilities and realistic fission product release and transport assumptions. For site evaluation in the Commission's safety review, extremely conservative assumptions are used for the purpose of comparing calculated doses resulting from a hypothetical release of fission products from the fuel against the 10 CFR Part 100 siting guidelines. Realistically computed doses that would be received by the population and environment from the accidents that are postulated would be significantly less than those to be presented in the Safety Evaluation.

The Commission issued guidance to applicants on September 1, 1971, requiring the consideration of a spectrum of accidents with assumptions as realistic as the state of knowledge permits. The applicant's response, in the ER, was evaluated, using the standard accident assumptions and guidance issued as a proposed amendment to (now) 10 CFR Part 51 by the Commission on December 1, 1971. Nine were identified by the Commission (Table 7.1). In general, accidents in the high potential consequence end of the spectrum have a low occurrence rate and those on the low potential consequence end have a higher occurrence rate. The examples selected are reasonably homogeneous in terms of probability within each class.

TABLE 7.1 Classification of Postulated Accidents and Occurrences

Class	AEC Description	Applicant's Examples
1	Trivial incidents	Evaluated as routine releases
2	Small releases outside containment	Evaluated as routine releases
3	Radioactive waste system failure	Partial and total releases of waste gas storage tank contents, release of liquid waste storage tank contents
4	Fission products to primary system (BWR)	Not applicable
5	Fission products to primary and secondary systems (PWR)	Off-design transients that induce fuel failures above those expected, steam generator tube rupture
6	Refueling accident	Fuel bundle drop, heavy object drop onto fuel in-core
7	Spent fuel handling accident	Fuel assembly drop in fuel storage pool, heavy object drop onto fuel rack, fuel cask drop
8	Accident initiation events considered in design-basis evaluation in the Safety Analysis Report	Small and large primary system pipe breaks, rod ejection accident, small and large steam line breaks
9	Hypothetical sequence of failures more severe than Class 8	Not considered

Table 7.2 presents Commission estimates of the dose that might be received by an assumed individual standing at the site boundary in the downwind direction, using the assumptions in the proposed amendment. Estimates of the integrated exposure that might be delivered to the population within 50 mi of the site are also presented in Table 7.2. The man-rem estimate was based on the projected population within 50 mi of the site for the year 2020.

To establish a realistic annual risk, the calculated doses in Table 7.2 would have to be multiplied by estimated probabilities. The events in Class 1 and 2 represent occurrences anticipated during plant operations; their consequences, which are very small, are considered within the framework of routine effluents from the plant. Except for a limited amount of fuel failures and some steam generator leakage, the events in Class 3 through 5 are not anticipated during plant operation; but they could occur sometime during the 40 yr plant lifetime. Accidents in Class 6 and 7 and small accidents in Class 8 are of lower probability than accidents in Classes 3 through 5 but are still possible. The probability of occurrence of large Class 8 accidents is very small. Therefore, when the consequences indicated in Table 7.2 are weighted by probabilities, the environmental risk is very low. The postulated occurrences in Class 9 involve sequences of successive failures more severe than those required to be considered in the design bases of protection systems and engineered safety features. Their consequences could be severe. However, the probability of their occurrence is judged so small that their environmental risk is extremely low. Defense in depth (multiple physical barriers), quality assurance for design, manufacture and operation, continued surveillance and testing, and conservative design are applied to provide and maintain assurance that potential accidents in this class are sufficiently small in probability as to carry an extremely low environmental risk.

The AEC currently is performing a study to assess these risks more quantitatively; initial results were made available in draft form August 20, 1974. It is an effort to develop realistic data on the probabilities and sequences of accidents in water cooled power reactors, in order to improve the quantification of available knowledge related to nuclear reactor accident probabilities. The Commission organized a group of 50 specialists to conduct the study under the direction of Norman Rasmussen of MIT. The scope of the study was discussed with EPA and described in correspondence placed in the AEC Public Document Room.[2] As with all new information developed that might have an effect on the health and safety of the public, the results of the study will be made public and will be assessed on a timely basis within the regulatory process on generic or specific bases as warranted.

Table 7.2 indicates the estimated radiological consequences of the postulated accidents would result in exposures of an assumed individual at the site boundary less than that resulting from a year's exposure to the Maximum Permissible Concentrations (MPC) of 10 CFR Part 20. The table also shows the estimated integrated exposure of the population within 50 mi of the plant from each postulated accident. Any of those integrated exposures would be much smaller than that from naturally occurring radioactivity. When considered with the probability of occurrence, the annual potential radiation exposure of the population from all the postulated accidents is smaller than exposure from natural background radiation and is well within variations in the natural background. The staff concludes from the analysis that the environmental risks due to postulated radiological accidents are exceedingly small and need not be considered further.

7.2 TRANSPORTATION ACCIDENTS INVOLVING RADIOACTIVE MATERIALS

The staff recently completed an analysis of the potential impact on the environment of transporting fuel and solid radioactive waste for nuclear power plants under existing regulations (Subsec 5.2.1.4.2).[3] The probabilities of occurrences of accidents and the expected consequences of such accidents were analyzed, as well as potential exposures to transport workers and the general public under normal conditions of transport.

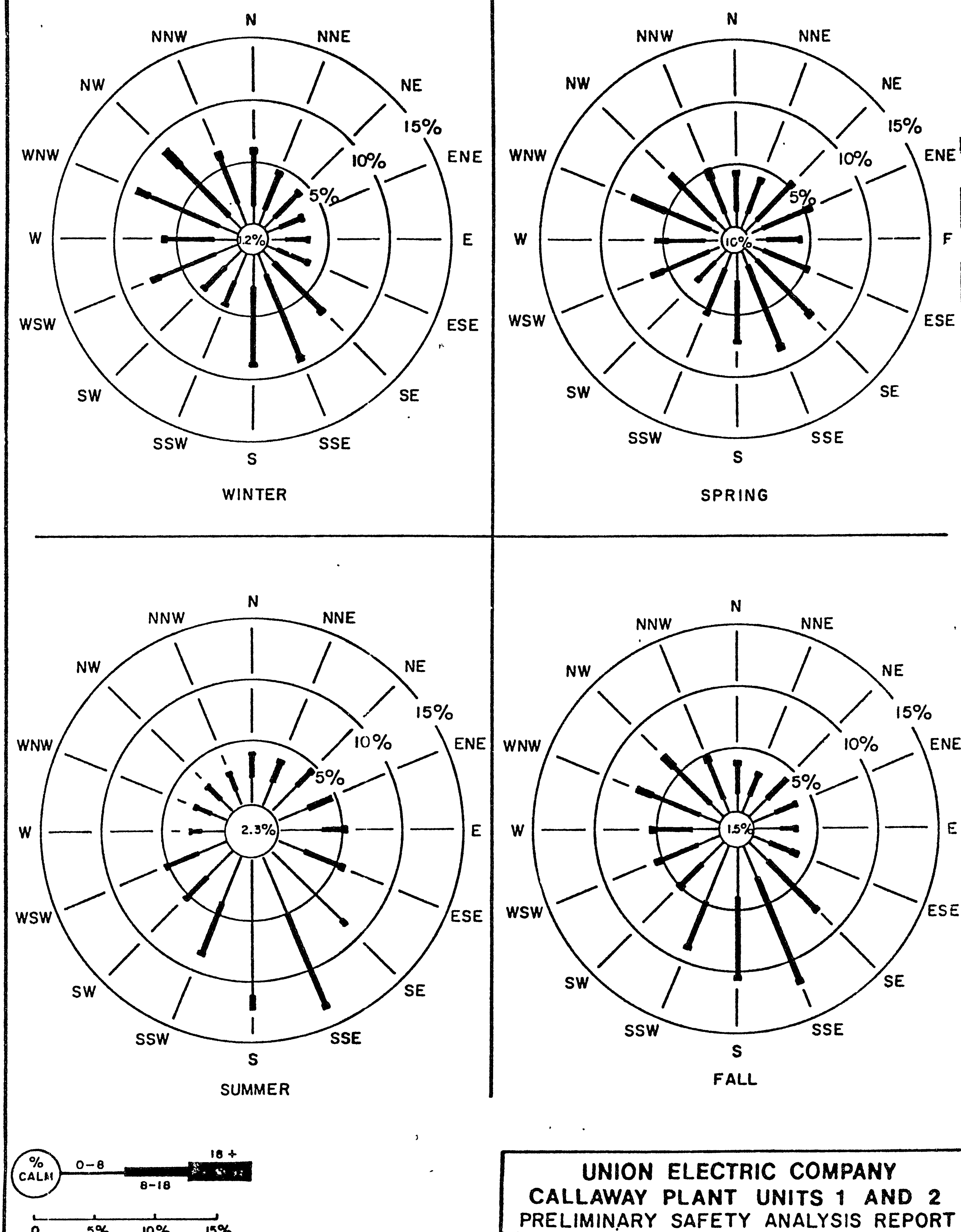
Characteristics of Callaway reactor fuel and waste and the conditions of transport for the fuel and waste will fall within the scope of the report.

Spent fuel elements removed from the reactors will be unchanged in appearance and will contain some of the original ^{235}U (which is recoverable). As a result of the irradiation and fissioning of the uranium, the fuel elements will contain large amounts of fission products and some plutonium. As the radioactivity decays, it will produce radiation and heat. The amount of radioactivity remaining in the fuel will vary with the length of time after discharge from the reactor. After removal from the reactors, the fuel elements will be placed under water in a storage pool to decay radioactively before being loaded into a cask for transport. The irradiated fuel elements will be shipped, after an appropriate decay period, in AEC-DOT approved casks designed for transport.

TABLE 7.2 Summary of Radiological Consequences of Postulated Accidents[a]

Class	Event	Estimated Fraction of 10 CFR Part 20 Limit at Site Boundary[b]	Estimated Dose to Population in 50 Mile Radius, man-rem
1.0	Trivial incidents	(c)	(c)
2.0	Small releases outside containment	(c)	(c)
3.0	Radwaste system failures		
3.1	Equipment leakage or malfunction	0.024	0.87
3.2	Release of waste gas storage tank contents	0.094	3.5
3.3	Release of liquid waste storage contents	0.003	0.1
4.0	Fission products to primary system (BWR)	N.A.	N.A.
5.0	Fission products to primary and secondary systems (PWR)		
5.1	Fuel cladding defects and steam generator leaks	(c)	(c)
5.2	Off-design transients that induce fuel failure above those expected and steam generator leak	<0.001	<0.1
5.3	Steam generator tube rupture	0.032	1.1
6.0	Refueling accidents		
6.1	Fuel bundle drop	0.005	0.2
6.2	Heavy object drop onto fuel in core	0.087	3.3
7.0	Spent fuel handling accident		
7.1	Fuel assembly drop in fuel rack	0.003	0.1
7.2	Heavy object drop onto fuel rack	0.013	0.4
7.3	Fuel cask drop	0.096	3.5
8.0	Accident initiation events considered in design basis evaluation in the SAR		
8.1	Loss-of-Coolant Accidents		
	Small Break	0.055	3.7
	Large Break	0.51	120
8.1(A)	Break in instrument line from primary system that penetrates the containment	N.A.	N.A.
8.2(B)	Rod ejection accident (PWR)	0.051	12
~~8.2(B)~~	~~Rod drop accident (BWR)~~	N.A.	N.A.
8.3(A)	Steamline breaks (PWR's outside containment)		
	Small Break	<0.00	<0.1
	Large Break	<0.001	<0.1
~~8.3(B)~~	~~Steamline break (BWR)~~	N.A.	N.A.

(a) The doses calculated as consequences of the postulated accidents are based on airborne transport of radioactive materials resulting in both a direct and an inhalation dose. The staff's evaluation of the accident doses assumes that the applicant's environmental monitoring program and appropriate additional monitoring (which could be initiated subsequent to a liquid release incident detected by in-plant monitoring) would detect the presence of radioactivity in the environment in a timely manner such that remedial action could be taken if necessary to limit exposure from other potential pathways to man.
(b) Represents the calculated fraction of a whole body dose of 500 mrem, or the equivalent dose to an organ.
(c) The releases are expected to be in accord with proposed Appendix I for routine effluents (i.e., 5 mrem per year to the whole body from either gaseous or liquid effluents).



REFERNCE
MISSOURI AIR CONSERVATION COMMISSION. 1970,
COLUMBIA, MISSOURI AIR POLLUTION SURVEY.
UNPUBLISHED REPORT.

UNION ELECTRIC COMPANY
CALLAWAY PLANT UNITS 1 AND 2
PRELIMINARY SAFETY ANALYSIS REPORT

FIGURE 2.3-5

SURFACE WIND ROSES FOR COLUMBIA, MISSOURI FOR THE PERIOD 1951 - 1959

FILE COPY

APPENDIX G

Final

environmental statement

related to operation of

COOPER NUCLEAR STATION

NEBRASKA PUBLIC POWER DISTRICT

Docket No. 50-298

February 1973

UNITED STATES ATOMIC ENERGY COMMISSION

DIRECTORATE OF LICENSING

II. THE SITE

A. LOCATION OF THE STATION

Cooper Station is located in Nemaha County, Nebraska, on the west bank of the Missouri River at river mile 532.5, referred to by the Corps of Engineers as the lower Brownville Bend. Site coordinates are approximately 40° 20' north latitude and 95° 38' west longitude. The site consists of 1090 acres of land, including 205 acres on the opposite bank of the Missouri River in Atchinson County, Missouri. The station is located on approximately 55 acres of this property on the Nebraska side of the river, of which about 30 acres were formerly farmland and 25 acres are between the flood control dike and the river. The site, in relation to population centers, is shown on Figure II-1. An aerial photograph of the site prior to construction is shown in Figure II-2.

B. REGIONAL DEMOGRAPHY AND LAND USE

The area in which Cooper Station is located is agricultural. Towns within a 50-mile radius (see Figure II-1) are small, primarily supporting the agriculture community. The nearest developed community is Brownville, 2-1/4 miles northwest of the site, with a population of 174 (1970 census). The next closest village is Nemaha, 2-1/2 miles southwest of the site, with a population of 207 (1970 census). The closest major city is Nebraska City, 24 miles northwest of the site, with a population of 7441 (1970 census). All cities exceeding 25,000 population are in excess of 50 miles from the site. A summary of the approximate population density within 50 miles of the site is indicated in Table II-1.

TABLE II-1

ESTIMATED POPULATION DENSITY IN THE AREA SURROUNDING COOPER NUCLEAR STATION

Distance	Approximate Population(a)		Projected Population(b)	
(Miles)	In Region	Accumulative	In Region	Accumulative
0-5	1,100	1,100	900	900
5-10	1,900	3,000	1,600	2,500
10-20	19,900	23,000	19,000	21,000
20-30	37,000	60,000	34,000	56,000
30-40	35,700	96,000	33,000	89,000
40-50	81,400	177,000	93,000	182,000

(a) 1970 Census
(b) 1980

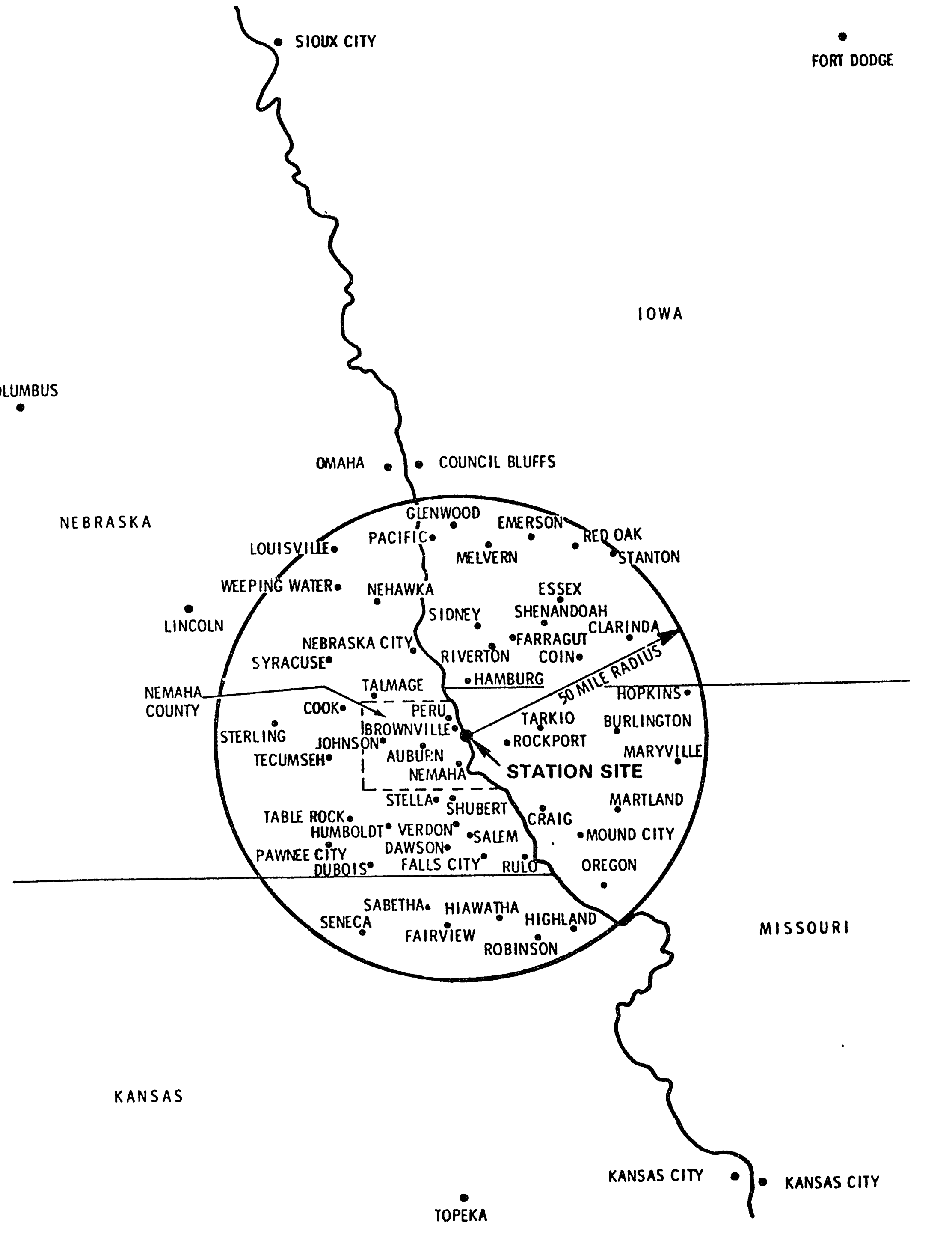


FIGURE II-1. A MAP OF THE VICINITY OF COOPER NUCLEAR STATION

Over 99% of the acreage in Nemaha County is used for agriculture, and farming is the major activity of the rest of the area within a 50-mile radius as well. The nearest farm residence is about 3500 ft SSW from the reactor. This farm feeds cattle for the market, using corn grown on the farm. The closest town with industry is Auburn, Nebraska, 10 miles west of the site. Other industry is located in Nebraska City (24 miles NNW), Marysville, Missouri (45 miles east), Shenandoah, Iowa (32 miles northeast), and Red Oak, Iowa (47 miles NNE). All industry in the area can be classified as "light". Little population growth is projected for the overall area as indicated by the accumulative figures in Table II-1. A shrinking of 5% to 10% is projected within a 40-mile radius and a growth of 11% is projected for the 40- to 50-mile region by 1980.

C. HISTORICAL SIGNIFICANCE

Two sites listed in the National Register of Historic Places are in close proximity to the station. Both were established on February 20, 1971.[1] The Brownville Historic District was established for the town of Brownville. Since bluffs exist between the town site and the station site, the station facilities are visible from only two of the buildings in Brownville and from the area adjacent to the Missouri River. The station is not visible from the downtown area where most of the historic buildings are located. The Mule Barn Theatre (David Rankin Mule Barn) is located in Tarkio, Missouri, 15 miles from the station site.

Other sites listed in the Federal Register[1] are 25 miles or farther from the site and include National Historic Landmarks designated as the Leary Site near Rulo, Nebraska in Richardson County, and the Gilmore (Walker) Site (Sterns Creek Site) near Murray, Nebraska in Cass County. The Nehawka Flint Quarries near Nehawka, Nebraska in Cass County and the Morton (J. Sterling) House in the vicinity of Nebraska City in Otoe are also listed. Cooper Station will have no impact on any of these sites.

D. ENVIRONMENTAL FEATURES

1. Geology

Cooper Station is located on the west bank of the Missouri River on the river side of the levee. Terrain is fairly level with the natural grade at about 890 ft above sea level. The site plan is shown in Figure II-3. Field explorations and laboratory tests for the site show that the upper 15 ft of surficial material consist of silt and clay which form an impervious layer unsuitable for foundation loadings. Below this impervious

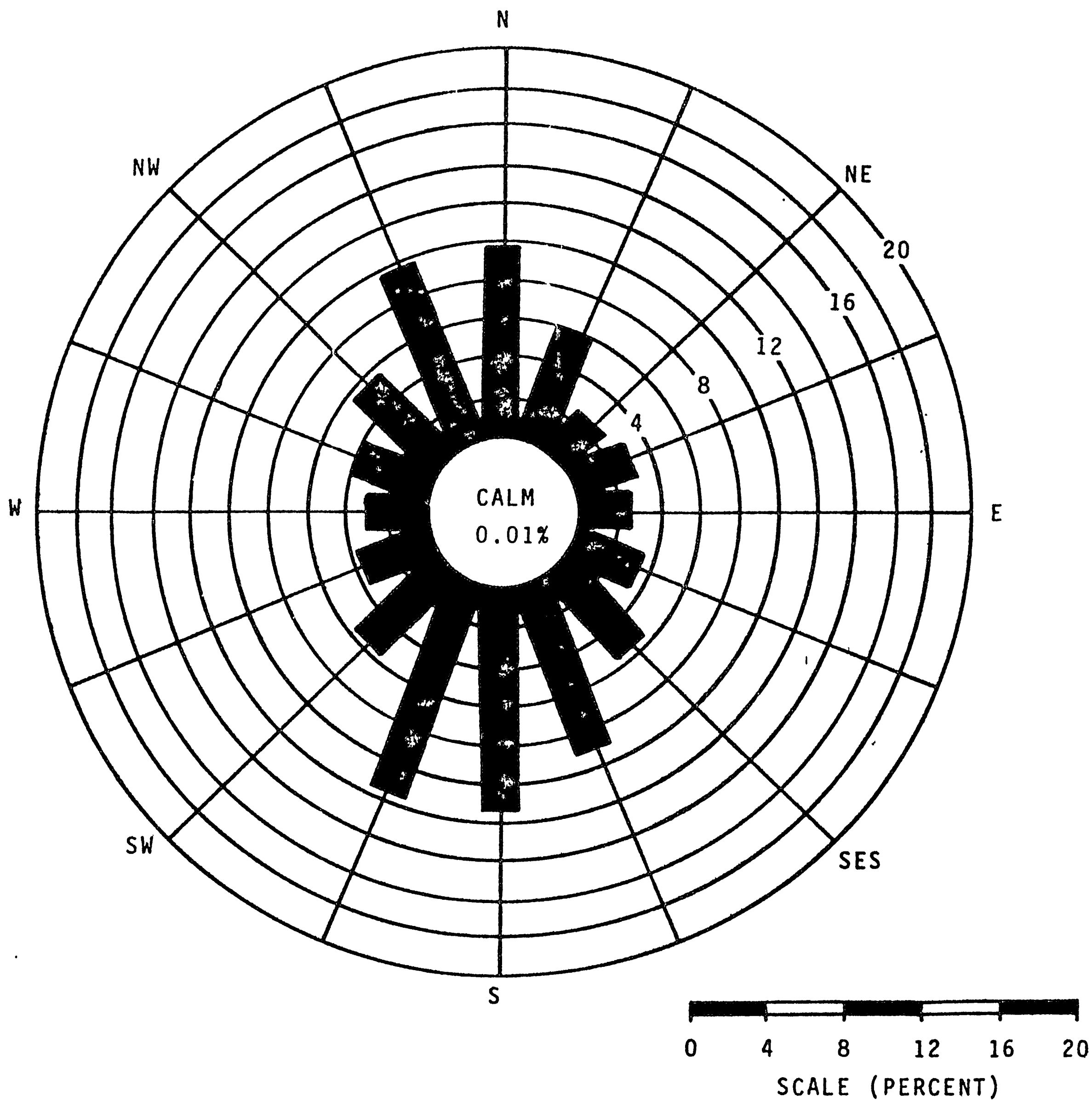


FIGURE II-6. COOPER STATION ANNUAL WIND ROSE, MARCH 1970 - FEBRUARY 1971 (All Observations Sample Size 8,178)

(Reproduced by the Colorado Department of Health, 1975)

APPENDIX H

SAMPLE "AGREEMENTS STATE" LEGISLATION (FROM COLORADO)

TITLE 25

ARTICLE 11

RADIATION CONTROL

25-11-101. Definitions. As used in this article, unless the context otherwise requires:

(1) "Department" means the department of health.

(2) "Ionizing radiation" means gamma rays and x-rays and alpha particles, beta particles, high-speed electrons, neutrons, protons, and other high-speed nuclear particles.

(3) "Radioactive material" means any material, solid, liquid, or gas, which emits ionizing radiation spontaneously.

25-11-102. Agreements for transfer of functions from federal government to state government. (1) The governor, on behalf of this state, is authorized, from time to time, to enter into agreements with the federal government providing for the assumption by this state through the department, and the discontinuance by the federal government, of any and all responsibilities within the state of Colorado relating to the protection of persons and property from the hazards of radioactive materials and other sources of ionizing radiation.

(2) The governor, on behalf of this state, is authorized, from time to time, to enter into agreements with the federal government, other states, or interstate agencies whereby the department shall perform, on a cooperative basis with the federal government, other states, or interstate agencies, inspections or other functions relating to control of sources of ionizing radiation.

(3) No such agreement entered into pursuant to the provisions of subsections (1) or (2) of this section shall transfer to, delegate to, or impose upon the department any power, authority, or responsibility that is not fully consistent with the provisions of this article.

25-11-103. Radiation control agency--powers and duties. (1) The department is designated as the radiation control agency of this state.

(2) Pursuant to rules and regulations as provided in section 25-11-104, the department shall issue licenses pertaining to radioactive materials and require registration of other sources of ionizing radiation. No other agency or branch of this state shall have such power or authority.

(3) The department shall develop and conduct programs for evaluation and control of hazards associated with the use of any and all radioactive materials and other sources of ionizing radiation.

(4) The department may institute training programs for the purpose of qualifying personnel to carry out the provisions of this article and may make said personnel available for participation in any program of the federal government, other states, or interstate agencies in furtherance of the purposes of this article.

(5) In the event of an emergency relating to any source of ionizing radiation which endangers the public peace, health, or safety, the department shall have the authority to issue such orders for the protection of the public health and safety as may be appropriate, including orders to lay an embargo upon or impound radioactive materials and other sources of ionizing radiation in the possession of any person who is not equipped to observe or who fails to observe the provisions of this article or any rules or regulations promulgated under this article.

(6) The department or its duly authorized representatives shall have the power to enter, at all reasonable times, into the areas in which sources of ionizing radiation are reasonably believed to be located for the purpose of determining whether or not the owner, occupant or licensee is in compliance with or in violation of the provisions of this article and the rules and regulations promulgated under this article, and the owner, occupant or person in charge of such property shall permit such entry and inspection.

(7) (a) In order to provide for the concentration, storage, or permanent disposal of radioactive materials consistent with adequate protection of the public health and safety, the state, through the department, may acquire by gift, transfer from another state department or agency, or other transfer any and all lands, buildings, and grounds suitable for such purposes. Any such acquisition shall be subject to the provisions of paragraph (h) of this subsection (7).

(b) The state, through the department, may, by lease or license with private persons or corporations, provide for the operation of sites or facilities, for the purposes stated in paragraph (a) of this subsection (7), in, under, and upon lands and grounds acquired under said paragraph (a) in accordance with rules and regulations established by the department; but no lease or license shall be authorized except with the prior approval of the state engineer. The department may permit the conduct thereon of other related activities, involving radioactive materials not contrary to the public interest, health, and safety. Each such lease or license shall cover only one site or facility and shall provide for a term up to ninety-nine years, which shall be renewable. Each such lease or

license shall provide for the payment to the state of a fee based upon the quantity of radioactive material stored in the lands covered thereby. Such fee shall be established at such rate that interest on the sum of all fees reasonably anticipated as payable under any lease or license shall provide an annual amount equal to the anticipated reasonable costs to the state of such maintenance, monitoring, and other supervision of the lands and facilities covered by such lease or license, following the term thereof, as are required in the interest of the public health and safety. In arriving at the rate of the fee, the department shall consider the nature of the material to be stored, the storage space available, estimated future receipts, and estimated future expenses of maintenance, monitoring, and supervision.

(c) Said lease shall include a payment in lieu of taxes which shall be paid over to local governmental units in compensation for loss of valuation for assessment. Said payment shall be adjusted annually to conform with current mill levies, assessment practices, and value of land and improvements.

(d) All fees provided in this section shall be paid quarterly, as accrued, to the department, which shall receipt for the same and shall transmit such payment to the state treasurer and take his receipt therefor.

(e) The department may require, as a condition to the issuance of any lease or license under paragraph (b) of this subsection (7), that the lessee or licensee give reasonable security for the payment of the amount of all fees reasonably anticipated during the full term of such lease or license, and the department may also require, as a condition to the issuance of any lease or license, that the lessee or licensee post a bond or other security under such regulation as the department may prescribe to cover any tortious act committed during the term of the lease or license.

(f) Prior to the issuance of any lease or license under paragraph (b) of this subsection (7), the department, at the expense of the applicant, shall hold a public hearing on the application, in the area of the proposed site or facility, after reasonable public notice.

(g) The operation of any and all sites and appurtenant facilities established for the purposes of paragraph (a) of this subsection (7) shall be under the direct supervision of the department and shall be in accordance with rules and regulations adopted under section 25-11-104.

(h) It is recognized by the general assembly that any site used for the concentration, disposal, or storage of radioactive material and the contents thereof will represent a continuing and perpetual responsibility involving the public health, safety, and general welfare and that ownership of said site and its contents must ultimately be reposed in a solvent government, without regard for the existence of any particular agency, instrumentality, department, division, or officer thereof. To this end and subject only to the terms of any lease or license issued under paragraph (b) of this subsection (7), all lands, buildings, and grounds acquired by the state under paragraph (a) of this subsection (7) which are used as sites for the concentration, storage, or disposal of radioactive materials shall be owned in fee simple absolute by the state and dedicated in perpetuity to such purposes, and all radioactive material received at such facility, upon permanent storage therein, shall become the property of the state and shall be in all respects administered, controlled, and disposed of, including transfer by sale, lease, loan, or otherwise, by the state, through the department, unless the general assembly shall designate another agency, instrumentality, department, or division of the state so to act.

25-11-104. Rules and regulations to be adopted. (1) The state board of health shall formulate, adopt, and promulgate rules and regulations as provided in subsection (2) of this section which shall cover subject matter relative to radioactive materials and other sources of ionizing radiation which shall include, but not be limited to: Licenses and registration, records, permissible levels of exposure, notification and reports of accidents, technical qualifications of personnel, handling, transportation and storage, waste disposal, posting and labeling of hazardous sources and areas, surveys, and monitoring.

(2) All such regulations shall be modeled after and shall be neither more nor less stringent than those proposed by the council of state governments, 1313 East Sixtieth Street, Chicago, Illinois, under the title, "Suggested State Regulations for Control of Radiation, October, 1964"; except that, in the event said board concludes on the basis of detailed findings that a substantial deviation from any of said suggested state regulations is warranted and that a substitute regulation or no regulation would effectively permit maximum utilization of sources of ionizing radiation consistent with the health and safety of all persons who might otherwise become exposed to such radiation, the board need not maintain such suggested state regulation or may adopt and promulgate such substitute regulation as the case may be.

(3) The rules and regulations adopted pursuant to this article shall never be construed to limit the kind or amount of radiation that may be intentionally applied to a person for diagnostic or therapeutic purposes by or under the direction of a duly licensed practitioner of the healing arts.

(4) Any person who, on the effective date of an agreement under section 25-11-102, possesses a license issued by the federal government shall be deemed to possess an identical license issued pursuant to this article subject to termination upon ninety days' written notice of termination from the department.

(5) In adopting, changing, and revoking said rules and regulations, the board shall comply with the provisions of article 4 of Title 24, C.R.S. 1973.

25-11-105. Radiation advisory committee. The governor shall appoint a radiation advisory committee of nine members, no more than four of whom shall represent any one political party and three of whom shall represent industry, three the healing arts, and three the public and private institutions of higher education. Members of the committee shall serve at the discretion of the governor and shall be reimbursed for necessary and actual expenses incurred in attendance at meetings or for authorized business of the board. The committee shall furnish to the department such technical advice as may be desirable or required on matters relating to the radiation control program.

25-11-106. Injunction proceedings. If, in the judgment of the department, any person has engaged in or is about to engage in any acts or practices which constitute a violation of any provision of this article or of any rule or regulation or order issued under this article, the attorney general shall, at the request of the department, make application to the district court for an order enjoining such acts or practices or for an order directing compliance with the provisions of this article and all rules, regulations, and orders issued under this article.

25-11-107. Prohibited acts--violations--penalties. (1) No person shall acquire, own, possess, or use any radioactive material occurring naturally or produced artificially without having been granted a license therefor from the department, nor shall he transfer to another or dispose of such material without first having been granted approval of the department therefor.

(2) No person shall knowingly use, manufacture, produce, transport, transfer, receive, send, acquire, own, or possess any source of ionizing radiation unless such person is licensed by or registered with the department.

(3) Any person who violates the provisions of subsections (1) and (2) of this section is guilty of a misdemeanor and, upon conviction thereof, shall be punished by a fine of not less than one hundred dollars nor more than five hundred dollars, or by imprisonment in the county jail for not less than thirty days nor more than ninety days, or by both such fine and imprisonment.

25-11-108. Exemptions. (1) The provisions of sections 25-11-103 and 25-11-104 shall not apply to the following sources or conditions:

(a) Electrical or other equipment or material that is not intended primarily to produce radiation and that, by nature of design, does not produce radiation at the point of nearest approach at a weekly rate higher than one-tenth the appropriate limit generally accepted by the medical profession for any critical organ exposed. The production testing or production servicing of such equipment shall not be exempt.

(b) Radiation machines during process of manufacture or in storage or transit. The production testing or production servicing of such machines shall not be exempt.

(c) Any radioactive material while being transported in conformity with regulations adopted by the atomic energy commission, or any successor thereto, or the interstate commerce commission and specifically applicable to the transportation of such radioactive materials.

(d) Sound and radio waves and visible infrared and ultraviolet light.

(2) No exemptions under this section are granted for those quantities or types of activities which do not comply with the established rules and regulations promulgated by the atomic energy commission, or any successor thereto.

(3) The provisions of section 25-11-107 shall not apply to unmined minerals containing radioactive materials, except such as are involved in mining operations.

EXCERPTS FROM

DEPARTMENT OF CONSUMER AFFAIRS, REGULATION AND LICENSING

PUBLIC SERVICE COMMISSION

REPORT OF THE STATE AUDITOR

THREE YEARS ENDED JUNE 30, 1974

(Pages 44, 45, and 46)

Commission Should Devise Consultant Approval Procedures

The commission secretary said consultants are screened by the most knowledgeable staff department for expertise and conflict of interest; then the commission, after proper study and interviews, votes to hire them. However, we found no formally adopted, written policy for screening and hiring consultants.

During our review, we found several instances where proper screening of C.P.A. firm consultants was implemented, but also discovered one significant case where "normal" or "understood" procedures were waived.

The commission hired the University of Missouri-Columbia nuclear engineering department to present testimony on Union Electric's proposed nuclear power plant although UE was subsidizing one department program and negotiating on another study. This apparent conflict of interest illustrates the lack of formal, written screening and approval policies for hiring consultants.

UE had paid the department $25,495 to sponsor "This Atomic World" lecture series from July, 1974 to May, 1975. Before July, 1974, the department proposed that Union Electric fund a research program in engineering problem solving for $68,870 annually for five years; the grant proposal noted several areas of uncertainty or difficulty which plagued nuclear power plants and needed further study. That proposal, in part, stated:

A typical example of current college efforts to deal with timely problems is the cooperative program between the electrical engineering department, nuclear engineering program, Union Electric Company, Fulton Chamber of Commerce and community leaders as well as environmental groups to explain the impact and economic advantages of building a nuclear power plant in mid-Missouri. Representatives of all concerned have already met twice and final plans are underway to hold two conferences in the spring dealing with both the technical and economical impacts. By informing the public with facts about nuclear power plants, myths would not be able to survive for long.

On September 24, 1974, the UMC nuclear engineering department signed an agreement with the PSC to, in part, "(e)valuate the evidence submitted by Union Electric Company in support of its application regarding plant design feasibility, technological feasibility, nature and quality of plant effluents, discharges and wastes, and bring to the attention of the commission counsel any areas of concern noted in this evaluation and the potential consequences of these concerns..." for $10,000.

On October 10, about two weeks later, the university professors filed their testimony which corroborated Union Electric's case on virtually every point. The professors seemed quite certain that the plant was safe and operable despite the multiple questions and "needs for further research" on nuclear power mentioned in their earlier engineering-problem-solving proposal.

On January 3, 1975, Union Electric approved a one-year grant of $20,000 for this proposal.

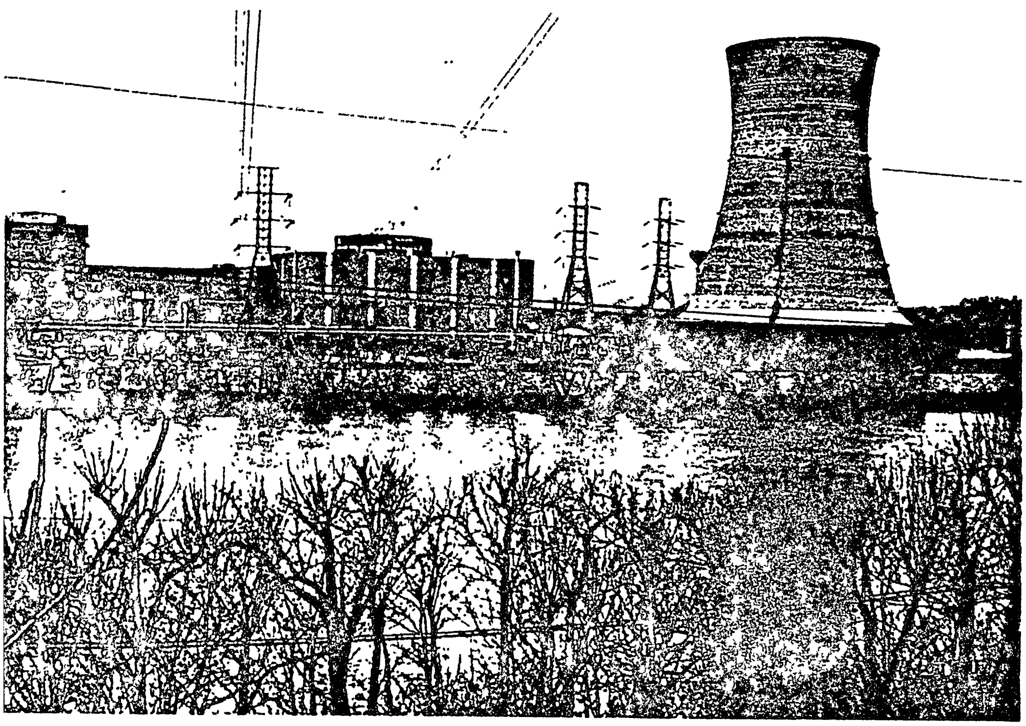
On March 14, 1975, the PSC issued its report and order approving the power plant construction, quoting the UMC professors as "unbiased, objective experts unconnected with the case" and using their testimony to help justify the decision.

According to an engineering department employee, the commission chairman suggested hiring the UMC department just before the hearings opened because the PSC discovered it had no staff members competent to testify on nuclear engineering. As a result, the commission dispensed with logical screening and approval procedures and encumbered $10,000 for questionable services.

The PSC should never hire consultants so closely involved with principals of the case. Although these arrangements may not have altered consultants' testimony, they certainly negate its public value as justification for the nuclear plant.

A Preliminary Report on Three Mile Island

The NRC learns of negligence, mechanical failure, and 48 hours of confusion in the control room



The guilty party, with cooling tower.

The accident at the Three Mile Island nuclear power plant was dangerously out of control for at least 48 hours, according to a preliminary staff report given to the Nuclear Regulatory Commission (NRC) on 4 April. That is how long it took the technicians to figure out with any certainty what had gone amiss. During the first 13½ hours after the accident began, the reactor core overheated and then began to disintegrate. Technicians stopped this process by a fortuitous action whose significance they did not fully grasp until much later.

A mistaken move during this early period—such as a prolonged attempt to depressurize the reactor vessel, which is actually what the plant operators had in mind on the first day—would have caused serious damage to the control machinery and possibly produced a disaster in Pennsylvania. While this explosive and extremely hazardous situation developed, the people of Harrisburg were given bland assurances that the reactor was under control and that they had nothing to fear. It was not until the third day of the accident, after the full extent of the danger became known, that Governor Richard Thornburgh announced that it might be a good idea for women and children to leave the immediate area, if they were so inclined. Many were.

The NRC staff report of 4 April reveals that good luck had as much to do with averting a catastrophe as good engineering. For 13½ hours, it appears, the reactor core was left partially exposed above the cooling water, while temperatures inside the reactor vessel climbed off the recording chart. Engineers in the control room realized that something inventive had to be done. As one NRC staffer said, "There was speculation . . . that there were voids or perhaps bubbles in the system." Fortunately for Harrisburg, in trying to collapse these imagined voids, the technicians repressurized the system and raised the water level to cover the reactor core. Had this decision not been made when it was, gas would have continued to fill the reactor vessel, ultimately reaching the pumps and threatening the only viable cooling mechanism. As it was, the damage was extensive, although not enough to trigger an irreversible meltdown.

Chance appears to have played an important part in ending the crisis; negligence was important in causing it. According to the NRC report, a key element in the cooling system—three auxiliary feedwater pumps—had been taken out of commission 2 weeks before the accident and left out. This was done in violation of federal regulations. NRC's director of nuclear reactor regulation, Harold Denton, said on 4 April: "The auxiliary feedwater pumps should have been operational. Had they been, we would have had a completely different outcome." Negligence joined with mechanical failure and sheer folly (a technician confusedly turned off the emergency cooling system at the peak of the crisis) to eliminate all the planned safety systems intended to keep the reactor from overheating. When the core overheated, it produced a new and unexpected problem, a 1000-cubic-foot bubble of hydrogen gas, an eventuality for which the local utility and the federal regulators were utterly unprepared.

It took 2 days to analyze this situation and another 3 days to get it under control. At this writing, the bubble has been dissolved and removed from the reactor core, but there is a possibility that a new bubble could form when the system is depressurized and cooled. For this reason, the plant is being cooled with exquisite care. According to Denton's projections, the job should be done by Easter, 15 April.

In its preliminary report to the commissioners, the NRC staff listed six major errors that contributed to the accident.

▶ The first was the failure to keep spare auxiliary feedwater pumps on-line as required by the NRC. Only one of four was operational on 28 March, leaving no margin of safety when the accident began at 4 a.m.

▶ Second, a relief valve in the primary coolant loop opened during the accident, as it should have, to let out overheated

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water. Then it failed to close. This caused a dangerous drop in pressure.

▶ Third, at least one water level indicator on the pressurizing system appears to have given a faulty reading, causing a technician to think the system was full of water when it was not. This made him think wrongly that the situation was under control.

▶ Fourth, when the emergency core cooling system came on automatically, which only happens when things are seriously amiss, another automatic system designed to contain radioactive leaks failed to come into play. The NRC rules say that this leak containment system should switch on simultaneously with the emergency cooling system.

▶ Fifth and sixth, technicians in the control room turned off the emergency and the primary cooling pumps. They should have been left on. No one knows why they were stopped.

The NRC staff described these and other technical blunders in considerable detail, but they did not explain why the public was not warned of the danger sooner. Commissioner Peter Bradford asked some searching questions on this score: For example, "What is there about what we have learned from this," he wanted to know, that in the future "would guarantee that we would not again go 48 hours with such a misconception of what the nature of the situation was?" Bradford brushed aside the technical answers and pointed out that "the Pennsylvania authorities should have been getting ready for asking people to move during those two days . . . and they weren't. They were going along . . . ." NRC staff member Edson Case cut in at this point: "I think the answer is, Commissioner Bradford, you learn from experience. We haven't had many of these experiences, if any."

Lacking practical experience, the NRC often relies on computer analyses for insight into what might happen in an accident. These are not a good substitute for the real thing, as the present case demonstrates. There were no guidelines for wrestling a 1000-cubic-foot bubble into submission. The NRC, as a result of its bout of practical experience in Pennsylvania, has set up a "bubble group" to think hard about the recent accident and come up with a computer program to deal with this anomaly should it recur.

Ignorance of bubble mechanics, however, does not seem a good excuse for the failure to alert the public of the dangers that were present on the morning of 28 March. Although the technicians did not know why, they did know that the reactor core had reached potentially catastrophic levels of pressure and temperature. The public learned of this several days later. The utility's failure to communicate this information quickly and the experts' confessed ignorance about the bubble do not augur well for the future of the nuclear program. Who can say with confidence now that the next accident will play itself out as docilely as this one has?—ELIOT MARSHALL

The Radiation Studies Begin

Although it is not yet possible to give a full inventory of the radioactive pollutants that escaped from the Three Mile Island nuclear plant, federal health officials recently put together some estimates of what has leaked out and of the probable effects on the health of Pennsylvanians in the vicinity. The picture is sketchy because no reliable system of monitoring radiation levels was in place until several days after the accident had begun, when federal officials fanned out across the countryside with their instruments.

By volume, the largest pollution hazard came in the form of the inert noble gases xenon and krypton. They do not combine with other chemicals or become fixed in the human ecosystem. The radioactive isotopes of these gases have brief half-lives, so that they decay within days. The nuclear plant began leaking radioactive gases on 28 March and continued to do so for at least 2 weeks afterward, steadily replenishing whatever had decayed. As a result, the 25,000 people who live within a 5-mile radius of the plant have been receiving radiation from the very beginning—in doses that ranged from about 1 to 2 millirems per hour during the first week, to around 0.1 millirem per hour now. At this writing, the Nuclear Regulatory Commission estimates that the maximum cumulative exposure for a person near the plant is approximately 100 millirems. This does not represent a significant dose in epidemiological terms. According to testimony given on 4 April by Joseph Califano, Secretary of Health, Education, and Welfare (HEW), a reasonable guess is that if 10,000 people are exposed to 1000 millirems of radiation, one additional fatal cancer will result.

While the plant's filters did not prevent xenon and krypton from leaking to the outside, they did prevent large leaks of highly toxic substances such as radioactive iodine and particulates. Iodine is chemically active and is quickly taken up by the human thyroid. Small amounts of iodine-131 and cesium-137 have been found in samples of milk and water taken near Three Mile Island. For iodine, the highest concentration found was about 41 picocuries per liter of milk, well below the emergency level of 12,000 picocuries per liter, the point at which the Food and Drug Administration (FDA) requires that cattle be put on uncontaminated feed. (China's most recent nuclear bomb test raised the iodine level in milk near Harrisburg to around 300 picocuries.) Cesium measurements also have been small.

At least one unmeasured and unauthorized release of radioactive water occurred early in the accident, when the plant operators flushed waste storage tanks into the Susquehanna River. There will be other uncontrolled spills of water, gas, and perhaps particulates as the plant is cooled and decontaminated. The biggest problem will be to dispose of 2 million cubic feet of radioactive gas and 270,000 gallons of radioactive water still in the building. This cleanup cannot begin for several months.

HEW has taken a few immediate steps to meet the crisis: Federal supplies of an iodine-blocking medicine have been rushed to Pennsylvania, 200 dosimeters placed around the plant to collect data on cumulative radiation levels, and a plethora of research projects set in motion. The FDA, at the urging of several concerned scientists, stockpiled enough potassium iodide last year to protect about 225,000 people in a major nuclear accident. (One of those who pressed the FDA to take this action, physicist Frank von Hippel, calculates that people as far as 200 miles downwind of a major iodine leak would need the protection.) Potassium iodide does its job by saturating the thyroid and blocking the path before the radioactive isotope can enter.

Meanwhile, the Center for Disease Control has begun to collect all known records on radioactive leaks from the plant and is developing a registry of all the workers for use in a prospective health study.—E.M.

Nuclear Power Crossroads?

Three Mile Reactor Accident Clouds Future of Industry

The Three Mile Island accident, the worst nuclear reactor accident in the nation's history, has touched off what portends to be a major public policy debate that could determine the future of the nuclear industry.

The events at the facility near Harrisburg, Pa., could be an exceptionally serious blow for an industry already reeling from financial troubles and widely publicized federal government actions that leave doubts about nuclear power safety.

Among the key developments were government repudiation of parts of the so-called Rasmussen report, which the industry cited to defend nuclear power safety, and federal closing of five plants because of questions about the capacity of the facilities to withstand earthquakes.

Moreover, the accident appears to give industry critics more leverage to turn congressional attention toward a larger emphasis on safety in the debates over licensing speedups and waste disposal.

Opinions on Impact

As events unfolded at the Three Mile Island facility, industry spokesmen refused to speculate on the impact the accident would have on construction of new nuclear reactors.

Critics of the industry, on the other hand, were predicting it was the beginning of the end for nuclear power generation in the United States.

The ultimate verdict on nuclear power will depend on official assessments of the severity of the accident, of the extent to which the reactor's overlapping safety systems failed and of just how close the plant came to a meltdown of the reactor core, the worst possible nuclear accident.

The industry's future also will depend on whether there is sufficient public concern about nuclear safety following the Three Mile Island events to prompt Congress to impose new demands on the industry.

However, there is little doubt that nuclear power safety has been called into question to an extent unprecedented in the industry's brief history and that the industry had been dealt a significant setback.

—*By Alan Berlow*

Public Perception Problem

"You can look at the situation in two ways," said an official with Westinghouse Electric Corp. who asked not to be identified.

"From a technical viewpoint Three Mile Island is no problem. It sounds bad but there was no major accident.... From the political point of view it's next to a disaster. And public perception determines the political view.... It looks like this incident will have a profound effect" on the industry.

The week's events left the public with a series of graphic images: top level government officials debating evacuation of a half million people; the voluntary evacuation of children and pregnant women; the federal government's deep involvement in the operation of the local utility; Pennsylvania's capital at Harrisburg temporarily reduced to a veritable ghost town as residents stayed inside; the Pentagon flying in tons of lead bricks to assist a team of government officials in bringing the overheated reactor under control, and the federal government flying in hundreds of thousands of bottles of potassium iodide to counteract absorbtion of radioactive iodine 131 in the event of a catastrophe.

It also was a week of news reports of industry spokesmen minimizing the safety risks of the accident, of contradictions by government officials taking a more cautious approach and of sharp challenges to both by nuclear experts and antinuclear groups.

The net result appears to have been increasing confusion among average citizens about nuclear power safety.

Cautiously assessing the accident during its early stages, President Carter said the events "will make all of us reassess our present safety regulations ... and probably lead inexorably toward even more stringent safety design mechanisms and standards."

Pennsylvania Sen. Richard Schweiker, R, said the accident showed that "we have seriously underestimated both the safety problems associated with nuclear power generation and our ability to cope with a nuclear emergency."

A grimmer view came from Rep. Morris K. Udall, D-Ariz., who chairs a House subcommittee that will handle nuclear legislation this year. He declared, "The aura of confidence in nuclear energy has been shattered."

Painting the Best Picture

Against a barrage of negative publicity, industry officials refused to speculate on the long-term implications of Three Mile Island.

Those who discussed the accident sought to portray it in its best light, insisting that no one had died, that the radiation had been contained, and that the reactor's safety system had worked to prevent a more serious accident.

Officials repeatedly referred to statements by Department of Energy Secretary James R. Schlesinger that "we will have to have nuclear power" to meet future energy needs.

Charles F. Luce, chairman of Consolidated Edison of New York, predicted: "When the need is looked at with the alternatives, nuclear will remain an important part of our future."

John Conway, president of the American Nuclear Energy Counsel, a major industry trade association, acknowledged that "public opinion has been affected" and that the public's

"You can look at the situation in two ways. From a technical viewpoint Three Mile Island is no problem. It sounds bad but there was no major accident. . . . From the political point of view it's next to a disaster. And public perception determines the political view."

—Westinghouse Electric Corp. official

States Hit on Atomic Accident Plans

Most state and local authorities in areas around nuclear power plants are unprepared to protect residents against accidents involving the release of harmful radiation. At the same time there is no federal policy on providing the public with evacuation and other information about responding to a nuclear accident.

Those are some of the conclusions of a year-long study by the General Accounting Office, the investigative arm of Congress, released March 30.

The GAO report concluded that "people living near fixed nuclear facilities are not well informed about potential hazards nor about the actions that may be necessary to avoid or minimize radiation exposure."

The report criticized the Nuclear Regulatory Commission for failing to make emergency evacuation plans part of the process for licensing reactors.

The GAO also recommended that emergency planning zones around nuclear reactors be increased to 10 from five miles. The report said the NRC's criteria for determining emergency-planning areas "do not consider the more serious types of accidents that could occur and do not consider the public exposure levels that may require some protective action."

The agency said no single federal agency was prepared to direct an emergency evacuation in the event of a major disaster.

The report concluded that only 10 of the 43 states with commercial or military reactors met all of the NRC's emergency planning and preparedness standards.

It found that while 41 states have "some type of peacetime nuclear emergency plan," only nine had tested their plans in full scale drills and 16 had never tested their plans at all.

The GAO recommended "annual emergency drills" involving state and local agencies and a coordinated federal, state and local effort to disseminate information to the public on the hazards of reactor accidents and protective actions that can be taken.

The investigative agency also found that utility operators have "discouraged efforts to inform the public" about the dangers posed by their reactors. "Facility operators did not appear concerned about the lack of information made available to the public. This reflects the attitude of most operators, namely, that there is little danger to the public from their facilities." The report said operators were "reluctant" to provide public information "for fear of creating public alarm that could result in new or prolonged . . . protest activities."

A similar attitude was found at the Department of Energy and at Defense Department facilities where the GAO said emergency preparedness is "almost nonexistent."

perception of the industry "right now is not good."

But he and others in the industry said it would be "premature" to speculate on the accident before all the facts are in and it is determined whether the accident is "anywhere near as bad as the media are making it out to be."

Conway and others in the industry were highly critical of what he called "wild and erroneous newspaper and television stories" which reported that thousands of people could die if there were further mechanical failures at Three Mile Island.

Immediate Impact

If most industry officials didn't care to talk about the long range implications of Three Mile Island, there was, nonetheless, some highly visible immediate fallout from the accident:

- Federal officials said that a lengthy shutdown of auxiliary cooling pumps by the company operating the Three Mile Island facility, a major violation of federal nuclear plant operating rules, contributed significantly to the accident.
- California Gov. Edmund G. Brown Jr. asked the Nuclear Regulatory Commission to close a nuclear plant near Sacramento as a precautionary measure.
- Babcock & Wilcox, the manufacturer of the Three Mile Island facility, faced the possibility that the Pennsylvania reactor might never be reopened and that eight other B&W reactors with similar designs would be temporarily closed.
- General Public Utilities, the owner of the Pennslvania plant, announced it was stopping all of its construction projects to pay for damages resulting from the accident.
- Records obtained by the Union of Concerned Scientists indicating that B&W plants had been plagued by operating problems in the last few years, raised questions about the federal government's commitment to assuring safety.
- Organized protests against nuclear power and against construction of specific plants were reported across the country as well as in Europe and Japan.
- Business losses in the Harrisburg area were reported to have been "substantial" as a result of the nuclear emergency.

Beleaguered Industry

Long before Three Mile Island became a household word, the nuclear industry was suffering serious problems.

For years the nuclear industry had developed under substantial federal outlays, virtually unimpeded by public opposition.

As recently as 1973 the industry was prospering with 41 new reactor orders. Only a decade ago it took less than eight years to go from the planning of a reactor to completing construction.

But in the last few years, nuclear power has come into hard times.

The licensing process now takes as long as 12 years or more.

Nuclear Regulatory Commission review of reactor safety requirements has intensified as have challenges by public interest groups in regulatory proceedings and the courts.

Industry Extinction

But the licensing process is only a small part of the industry's problem. The major issue facing the industry, certain to be exacerbated by Three Mile Island, is its economic viability.

Since the Arab oil embargo of 1973, rapidly escalating energy costs, including dramatically higher electric bills, have forced many consumers to conserve power.

Prior to the oil embargo energy demand in the United States had been growing at the rate of 7 percent a year. Since then it has averaged about 3.5 percent. It was 2.7 percent in 1978.

Decreased consumer demand has led to fewer reactor orders. In 1975 utilities placed only five new reactor orders. In 1976 the number dropped to three.

Unless new reactor orders come soon, wrote Craig Hosmer, then-president of the American Nuclear Energy Council in October 1977, "the U.S. nuclear industry will move quietly to extinction."

The reactor orders didn't come. In 1977 four orders were placed. In 1978, two.

Add to the paucity of new orders, cancellations of old ones. In the last four years 31 reactor orders have been deferred or canceled. The industry is now living off back orders and will continue to survive on them until the early 1980's. But without new orders it is unlikely to survive.

Fewer Operating Plants

Only a few years ago the nuclear industry was predicting that it would have 1,000 plants operating by the year 2,000. Now the federal government projects that only 230 new plants will be added by the turn of the century.

Presently there are some 72 reactors licensed to operate in the U.S. providing about 12.5 percent of the nation's electric supply. An additional 92 plants have received construction permits.

The most optimistic projections of the industry's growth call for only 16 new reactor orders a year between 1980 and 1992.

That would average out to four reactors a year for each of the major manufacturers — General Electric, Westinghouse Electric Corp., Babcock & Wilcox and Combustion Engineering Inc. The four reactor vendors are able to deliver about 30 reactors annually and need an estimated four to six new orders a year to remain financially viable.

Compounding these problems is the fact that the industry put virtually all of its money into producing large reactors which produce substantial surpluses of generating capacity.

Nuclear power critics insist that the 30 percent reserve capacity of existing reactors along with reserves at fossil fuel plants are adequate to ease the country out of nuclear energy entirely by the end of the century.

1979: A Very Bad Year

Industry spokesmen all agree that nuclear energy will have no future unless the technology has public support. But thus far, 1979 has produced a series of events greatly undermining the industry's credibility.

In January the Nuclear Regulatory Commission repudiated sections of a 1975 study done by Dr. Norman Rasmussen, a Massachusetts Institute of Technology physicist.

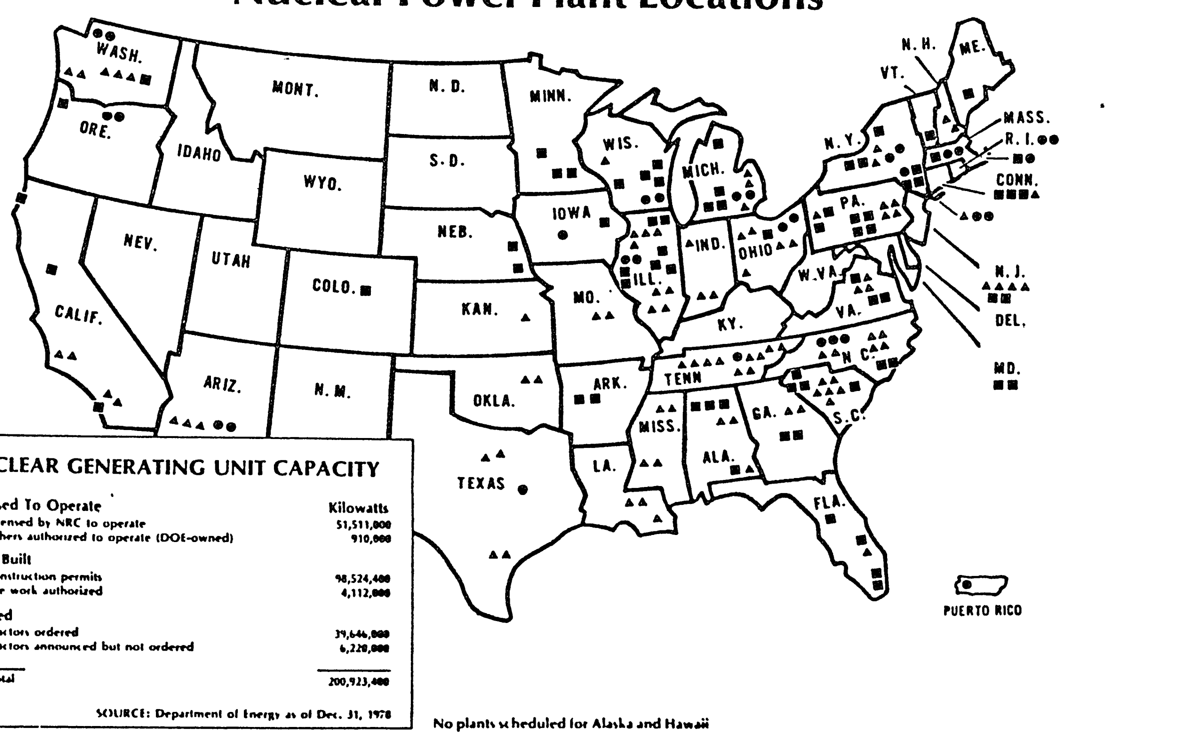
The Rasmussen report, which estimated the chances of various types of nuclear accidents, had been used by the industry to support its contention that the technology was safe.

Later the same month, the Union of Concerned Scientists, the most highly respected of the groups criticizing the industry, called on the government to shut down 16 U.S. reactors because of safety problems.

On March 13, shortly before the Three Mile Island accident, the Nuclear Regulatory Commission ordered the shutdown of five nuclear plants after it determined that a computer model used to determine their ability to resist earthquakes had been faulty.

The same day a special 14-agency governmental review unit raised questions about the scientific and technical feasibility of safely disposing of radioactive wastes created by commercial reactors. The report called into question a matter the industry has long argued it would have no problem resolving.

Nuclear Power Plant Locations



NUCLEAR GENERATING UNIT CAPACITY

	Kilowatts
■ Licensed To Operate	
78 licensed by NRC to operate	51,511,000
2 others authorized to operate (DOE-owned)	910,000
▲ Being Built	
90 construction permits	98,524,400
4 site work authorized	4,112,000
● Planned	
34 reactors ordered	39,646,000
5 reactors announced but not ordered	6,220,000
205 Total	200,923,400

SOURCE: Department of Energy as of Dec. 31, 1978

No plants scheduled for Alaska and Hawaii

As events at Three Mile Island unfolded, the General Accounting Office released a report that said local and state authorities in areas surrounding nuclear facilities — including those in Pennsylvania — were unprepared for a mass evacuation in the event of a serious accident. *(Box, p. 628)*

Meanwhile the industry has braced against the unknown impact of a highly popular Jane Fonda movie, "The China Syndrome," in which a nuclear accident is dramatized and in which one character remarks: "A major accident would render an area the size of Pennsylvania permanently uninhabitable."

Good News/Bad News

The kind of news that would provide the nuclear industry a boost would probably be bad news for energy consumers.

Another Arab oil embargo, continued escalation of oil prices or frequent electrical brownouts from high power consumption might result in more public pressure for rapid development of nuclear energy.

Probably the major unknown element in an assessment of nuclear power's future is whether the Three Mile Island accident will increase public concern for safety and whether the threat of a future nuclear plant accident will be strong enough to balance consumer concern about rapidly escalating oil and gas prices.

The Department of Energy has already reported energy supply problems as the result of nuclear plant closings in March. Officials have predicted serious problems if there are further plant closings in the summer when electric use is largest.

Legislative Battles

Both the nuclear industry and its critics were looking to the 96th Congress to resolve some of the fundamental controversies about nuclear power. Until the Three Mile Island incident, it appeared that the industry viewpoint was receiving more attention.

View of Industry

Three Mile Island hasn't changed the industry's priorities but it undoubtedly will affect the chances of success. The events also could have a significant impact on a range of new legislation likely to be offered by nuclear critics.

Industry officials had hoped for legislation on temporary storage of spent fuel and permanent storage of nuclear waste, a commitment from Congress to development of the fast breeder reactor and regulatory changes to speed the nuclear plant licensing process.

Westinghouse and General Electric were preparing an intense lobbying campaign this year. A utility trade association, The Edison Electric Institute, had planned to commit $5 million to a newspaper and magazine advertising campaign designed to win public support for nuclear reactors. The group spent $3.5 million last year.

Most industry representatives interviewed said their top priority was a speedup in the licensing process. Although Congress rejected an administration licensing bill in 1978, the industry hoped the proposal would get more serious attention this year.

Edwin Wiggins, executive vice president of the Atomic Industrial Forum, the industry's principal trade association, said, "Today the one big hangup is uncertainty. The problem is that in the 12 years it takes to put a reactor on line they [the Nuclear Regulatory Commission] reinvent the wheel," placing new operating requirements on reactors that hadn't been anticipated.

"The real question is what utility executives and those getting ready to order new capacity think. If you speed up the licensing process the system theoretically becomes more predictable," he said. If the system is more predictable, the industry concludes, more reactors will be sold.

View of Industry Critics

Anti-nuclear groups were considering a similar list of legislative priorities, but from a different perspective.

Marc Messing, a nuclear expert with the Environmental Policy Center, said "We want both licensing and waste bills, a clear federal program for nuclear management ... embodying three principles: complete design information for power plants before beginning construction, explicit inclusion of waste disposal and decomissioning costs in license applications and state veto authority over licensing decisions."

A well-organized coalition of environmental and solar energy advocates along with anti-nuclear critics were preparing to dispute the industry's case for speeded up licensing.

Messing said delays from licensing are a "myth." James Cubie, an aide to Sen. Edward M. Kennedy, D-Mass., and former counsel to the Union of Concerned Scientists, argued that "the industry wants to make delay and the critics a scapegoat so they don't have to face the facts of their own economic situation."

Nuclear critics insist that the licensing process is taking longer because there is less demand to bring facilities on line.

Waste: A Key Issue

The two sides were also preparing for a fight over the waste issue, which many industry spokesmen view as even more important to the industry's future than the licensing issue.

"We're going to have problems with public perception until the issue of long-term waste disposal is answered," said Loring Mills, manager of nuclear activities for the Edison Electric Institute, an association of investor-owned power companies.

"It's getting to the point where public perception is such that if we don't get an answer this year, we can't go forward," he said.

Mills indicated that the industry is particularly concerned about laws enacted in states such as Wisconsin prohibiting licensing of reactors until a determination is made about what to do with reactor wastes.

As Messing suggested, tying resolution of the waste situation — which some critics say is unsolvable — to the licensing process is a key component of the anti-nuclear strategy.

The waste issue is one with which the industry is particularly uncomfortable.

Donald Graham, Washington representative of the American Nuclear Society, argued that most wastes are not generated by commercial reactors but by nuclear weapons programs.

"It's our problem because the nuclear critics have ... only attacked the issue in the commercial sector where licensing is involved," he said.

Most representatives of the commercial nuclear industry deny they have a "waste" problem. They insist "spent fuel" from commercial reactors is not waste because it can eventually be recycled in the breeder reactor.

But there is no breeder reactor currently and its future is in serious doubt. Although Congress has supported the breeder in the past, President Carter has opposed it.

Political Fallout from Three Mile Island

Slower growth of nuclear power and strict regulation of reactors is called for by some key members of Congress

The era of commercial nuclear power opened in Pennsylvania 22 years ago when the first small 60-megawatt reactor went on line at Shippingport. Since then, nuclear generation has grown rapidly and last year contributed more than 12 percent, or 300 billion kilowatt hours, of the nation's total electric output. But with the events at the Three Mile Island power station, Pennsylvania has become the scene of a crisis that will slow further development of nuclear energy and may cause a drastic downturn.

The political fallout from Three Mile Island is such that it now seems unlikely that President Jimmy Carter—contrary to what Secretary of Energy James R. Schlesinger has been urging—will call for a major new push for nuclear power as part of the national energy plan. The President has indicated that he will be emphasizing greater reactor safety and the finding of a safe solution to the politically vexing problem of radioactive waste disposal.

The Three Mile Island incident has given a new credibility to antinuclear groups such as the Union of Concerned Scientists (UCS) and provoked an outcry by members of Congress for more effective licensing and oversight of reactor operations by the Nuclear Regulatory Commission (NRC). Already, there is a possibility that eight other nuclear plants—all similar to Three Mile Island unit No. 2 and built by the same company (Babcock and Wilcox)—will either be temporarily shut down or required to operate at well below their maximum generating capacity.

After the alarming nature of the situation at Three Mile Island first became evident, Representative Morris Udall (D-Ariz.), chairman of the House Interior Subcommittee on Energy, observed that the Three Mile Island incident is another in a "series of events that lends credence to the contentions of those who think we have rushed headlong into a dangerous technology." Despite all past assurances that the probability of multiple failures of safety systems is slight, Udall said, such failures had indeed occurred, with the trouble compounded by one or more instances of human error. In his view, the Three Mile Island crisis pointed up the NRC's "wisdom" in recently shutting down five reactors in the eastern United States after the discovery that a computer modeling error had resulted in some cooling system piping being below standard for stress resistance in the event of an earthquake.

Appearing on a television interview program along with the staunchly pronuclear Norman Rasmussen of the Massachusetts Institute of Technology, Udall said that the "incredibly optimistic" view which people held of nuclear technology in the 1950's and 1960's has been shaken, so much so that the nuclear enterprise might simply be allowed to wind down. Reactors now operating or under construction might not be replaced once they wear out, he suggested. "It [the prospect for nuclear power] is pretty bleak," Udall said. "I'm more pessimistic than I was a week ago."

If Udall had lost all of his "technological optimism," Rasmussen still had his. Rasmussen, so stolid and unflappable that at times he appeared graven in stone, plainly did not see the Three Mile Island incident as significantly undercutting the findings of the Reactor Safety Study which he directed for the NRC, although he conceded that it might "cause us to raise our probability figures somewhat."

In his response to the Three Mile Island incident, Senator Edward M. Kennedy (D-Mass.), chairman of an energy subcommittee of the Joint Economic Committee, spoke out against a Schlesinger proposal for a speed up in nuclear plant licensing. "It is more important to build these plants safely than it is to build them quickly," he said.

The chairman of the Senate Nuclear Regulation Subcommittee, Senator Gary Hart (D-Colo.), will offer legislation to establish continuous federal monitoring of all reactors and to have federal experts ready at all times to intervene in any crisis that arises and take full control. Under another Hart proposal, all states in which nuclear reactors are situated would prepare and rehearse emergency plans for evacuating communities near those reactors.

The Democratic majority leader, Senator Robert C. Byrd, also has said that the Pennsylvania incident raises "serious questions" about the safety of nuclear energy, and has called—somewhat opportunistically—for a greater reliance on coal, which his state of West Virginia produces in abundance.

At present, nuclear generating capacity in the United States totals 52,396 megawatts, and is provided by 72 fully licensed reactors, including at least six now shut down temporarily for reasons of public health and safety. This compares with the goal set forth by the Carter Administration 2 years ago to have 380,000 megawatts of installed capacity by the year 2000, a goal which the nuclear industry has regarded as excessively modest.

But there is now reason to wonder whether installed capacity will rise even to the 192,738 megawatt level which can be achieved if work on the 92 reactors already licensed for construction is completed and if licensing and construction of the other 34 which utilities have ordered actually goes forward. Even in 1978, prior to the onset of the present wave of troubles, 12 orders were cancelled, most of them because of lowered projections of future power demand and the financial squeeze in which many utilities find themselves. But two cancellations resulted from the state of California's refusal to allow the San Diego Gas and Electric Company to build Sundesert units 1 and 2 in the absence of a federally demonstrated and approved technology for permanent disposal of radioactive wastes.

California utilities are used to heavy political and regulatory weather, and, in nuclear matters, the worst of it often comes from Sacramento and not Washington. In the present situation, Governor Jerry Brown seems to have gone further than any Washington official by urging that the Rancho Seco nuclear unit, a sibling of Three Mile Island unit No. 2, be shut down for a thorough safety inspection. As NRC records bear out, Rancho Seco had some trouble last year with its integrated safety control system.

The thinking of utility executives across the nation about nuclear power may turn partly on whether the stricken Three Mile Island reactor can be returned to service, or whether it becomes a "billion dollar mausoleum." Some NRC officials see the latter as a real possibility.

Nuclear industry spokesmen have been trying to keep their courage up by suggesting to reporters that, short of a

disastrous meltdown or explosion, the Three Mile Island incident would not be too damaging to the industry and might even turn out to be a plus by demonstrating that safety backup systems had ultimately worked. In fact, if nuclear power does not go into a decline after Three Mile Island it may be only because coal is the only other near-term alternative to oil and natural gas for power generation, and coal is dirty. "If it weren't for coal, we'd be dead," a nuclear industry official told this reporter last year, long before the present uproar.

By the same token, the proponents of energy conservation and solar energy see the Three Mile Island crisis as an opportunity to win support for a greater national effort in these fields. The Council on Environmental Quality will, according to Gus Speth, a council member, be working within the Administration to that end. A recent CEQ publication *The Good News About Energy*, which stresses the advantages of conservation, indicates that economic prosperity through this century is possible without building any more coal-fired or nuclear plants than the number now under construction.—LUTHER J. CARTER

APPENDIX M

Low-Level Radiation: A High-Level Concern

The federal government is gearing up to reevaluate its research and regulatory responsibilities

Over the past year, in what some regard as a rather impressive shift, the federal government has made it clear that the problem of low-level radiation is an important one that needs to be addressed in a more orderly and responsible manner than has hitherto been the case.

The question everyone wants an answer to is this: Are current exposure limits, for workers and the general public, safe? At the same time, two broad institutional issues require sorting out. One is related to setting exposure guidelines and the degree of centralization there should be in promulgating specific regulations. The other, which promises a sustained period of interagency wrangling, is related to the question of who in the federal government should have primary responsibility for research on the health effects of radiation. This has long been the domain of the atomic energy establishment, now embedded in the Department of Energy (DOE). Many think it is time for the Department of Health, Education, and Welfare (HEW) to take the leading role.

Low-level ionizing radiation has become the focus of one of the longer-running scientific debates of our time. Although the major mistakes—notably, exposure of troops and civilians to radiation and fallout from aboveground atomic tests—are now in the past, their legacy persists in the form of simmering uranium mine tailings, cancer deaths allegedly caused by radiation, and perhaps most pertinent to the present, pervasive public mistrust of the DOE and the Department of Defense, agencies believed by some observers to have covered up the true extent of the hazards.

Nature supplies half the radiation the average human being is exposed to in a lifetime. Of man-made radiation, 90 percent is generated in medical uses. The other 10 percent is accounted for by occupational exposure, mostly in jobs in the nuclear fuel cycle (from uranium mining to nuclear waste disposal) and nuclear weapons testing.

It is the last 10 percent that has been the focus of most of the controversy. Two developments have contributed largely to turning the issue from a chronic, low-visibility one into a chronic, highly publicized one. The first has been DOE's decision (and its clumsy explanation for it) to terminate a long-term research contract with Thomas Mancuso of the University of Pittsburgh. Mancuso was cut loose shortly before he started coming up with findings linking some cancer deaths among workers at the government's Hanford Reservation with their exposure to low-level radiation.

The other development was the finding by HEW's Center for Disease Control that troops who had participated in a 1957 bomb test called Smoky had twice the number of leukemia deaths (eight instead of four) as would be expected from the prevalence of the disease in the general population.

The President, responding to rising concern in Congress, last summer appointed an Interagency Task Force on Ionizing Radiation, headed by HEW general counsel Peter Libassi, to figure out what the federal government's approach should be to the problem of the health effects of low-level radiation. The group's report, issued in March, has produced a number of initiatives. First, Donald S. Fredrickson, head of the National Institutes of Health, has been assigned to oversee a comprehensive evaluation of all federal research on the biological effects of radiation, a job that will probably enlist the services of the National Academy of Sciences (NAS). In addition, William Foege, head of the Center for Disease Control (CDC), is to design a research program on occupational exposure to radiation. This will include a study of deaths among employees of Portsmouth Naval Shipyard in New Hampshire, which is already being conducted by the National Institute for Occupational Safety and Health (NIOSH, part of the CDC). In addition, the Food and Drug Administration is to work harder with state governments and medical groups to develop ways to lower overall public exposure to medical x-rays. Still to come is a task force report outlining ways in which institutional arrangements can be changed to make for better coordination in both research and regulation.

The reports, although detailed, are predictably cautious. (The group "drew a conclusion, and that is that the science is inconclusive," said Libassi.) They were the subject of a recent Senate hearing at which they were criticized by some witnesses, including Edward P. Radford, chairman of the NAS committee on the Biological Effects of Ionizing Radiation (BEIR), who said that "bland, noncontroversial reports of this kind are the rule in the science policy area, unfortunately." Nonetheless, it is significant that the President put HEW in charge of assessing the research. In the opinion of a spokesman for the International Association of Machinists and Aerospace Workers, which has 25,000 members in nuclear occupations, issuance of the reports "was the beginning of an admission by the government that we've got a hell of a problem."

The political and scientific issues are inseparable, as illustrated by the Mancuso affair. In 1964 Mancuso was

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awarded a contract by the Atomic Energy Commission to conduct what has become the largest and longest-running study ever made of the human health effects of low-level radiation. His subjects were 35,000 former and current employees at the Hanford (Washington) Reservation and 112,000 workers from three installations run by Oak Ridge Associated Universities (ORAU) in Tennessee. The trouble began in 1974, when Washington state epidemiologist Samuel Milham, in a survey of death records in the state, found what appeared to be an excess of leukemia deaths among workers at the Hanford facility. The AEC's response to this finding was to urge Mancuso to refute it and to publish the negative results of his own preliminary analyses of the Hanford data. This Mancuso refused to do, saying he still did not have enough information. In March 1975 the AEC decided to phase out the Mancuso contract by mid-1977 and transfer the project to its in-house human health study group at ORAU.

Thomas Mancuso

According to documents later obtained through the Freedom of Information Act by Mancuso's lawyer, officials at AEC (later the Energy Research and Development Administration, or ERDA) were feeling uncomfortable about Mancuso's study throughout the 1970's. Even though peer reviewers consistently affirmed the validity of the project, AEC officials were writing memos to each other complaining about the "inordinately slow rate" at which findings were published, calling Mancuso "ineffective" as principal investigator, and expressing doubts that any useful information at all could be gained from the study. In 1976, Mancuso announced that analysis of the Hanford data indicated that 6 percent of the cancer deaths of Hanford employees (about 30) could be attributed to low-level radiation. ERDA, once eager to have Mancuso come out with something in writing, tried to delay publication of the findings, which appeared in the *Journal of Health Physics* in December 1977.

Even though the decision to terminate the Mancuso contract was made a year before he announced positive findings, environmental groups in 1976 jumped on ERDA, charging that the termination "reflects a well defined pattern of harassment and intimidation of scientists who do not agree with promoters of radiation technology."

Such was the fuss that had built up that the House health subcommittee, then chaired by Paul Rogers (D-Fla.), held 2 days of hearings in February 1978 in which the Mancuso matter was discussed at great length. The DOE did not come out looking good. James Liverman, then DOE's assistant secretary of environment, claimed that Mancuso had been dropped because of his "imminent retirement" from the University of Pittsburgh. Mancuso was 62 in 1975, 8 years under the Pittsburgh retirement age. It was also disclosed at the hearings that the transfer of the project to Oak Ridge had not been preceded by a request for proposal, that there was no peer review of the contractors, no research protocol, and no principal investigator. Rogers subsequently wrote a brusque letter to Energy Secretary James Schlesinger asking what he was going to do about the "serious management deficiencies" in DOE's radiation health effects research program.

DOE's inspector general subsequently reported that the handling of the Mancuso termination was proper; then the General Accounting Office, at Rogers' request, reviewed the inspector general's report. It criticized the decision to transfer the research to in-house labs, but did not find evidence that the contract termination was scurrilously motivated.

But the matter festers on. Mancuso and his supporters, including several labor unions, continue to believe he was cut off because he was finding things the DOE did not want to know, and further—a claim bolstered by old AEC correspondence—that the only reason for funding him in the first place had been "political"—to quell the public's fear about radiation and fend off compensation claims from people who believed they had radiation-induced illness.

It seems clear to DOE's critics that Mancuso was left to shift for himself just at the point where he was prepared to draw some solid conclusions from the Hanford data. Mancuso, now limping along with private funds (he hopes to get some money from HEW), says it will not be long before he has essentially completed the Hanford analysis—all he needs to do is get data on deaths in the late 1970's. He expects that his 6 percent figure may undergo an upward revision because the new data will be from workers who were younger than the ones already analyzed and who held jobs that exposed them to more radiation than the older workers.

Meanwhile, Mancuso's former funds have been transferred to ORAU for the Oak Ridge studies and to Battelle Labs for further analysis of the Hanford data. The Oak Ridge portion still does not have a principal investigator, although they are said to be looking for an epidemiologist; people at Battelle are conducting their own analyses, which Mancuso says are flawed because the investigators are not controlling for internal radiation. (Some workers also inhaled or ingested radioactive particles, but internal radiation has not received much attention so far, partly because the affected population is small.)

Although Mancuso is not now particularly happy, he can take solace in the fact that his case has helped coalesce a good deal of the current pressure to reduce the role of DOE in health effects research. The radiation research community has lived almost entirely off the energy and defense establishments. The situation is conducive to a monolithic approach to research and makes for at least the appearance of a conflict of interest. It also means that for anyone seeking objective scientific advice it is practically impossible to find someone knowledgeable who was not trained with AEC money.

Last month the DOE monopoly came in for some raps at 2 days of hearings conducted by John Glenn (D-Ohio), chairman of the energy subcommittee of the Senate Governmental Affairs Committee. Radford, chairman of the BEIR committee, noted that DOE controls 78 percent of the government's $17 million budget for research on human health effects of radiation. Most of the rest is from HEW. He said that 36 percent of the money has gone to government labs, 39 percent to the Hiroshima-Nagasaki studies, and 13 percent to in-house research. This has left only 5 percent for university researchers and 5 percent for nongovernmental groups.

"The science is in the wrong hands. The DOE budget (for health effects research) should be cut by 90 percent," a scientist who did not want to be quoted told *Science*. "The DOE says they don't have enough data, but whose fault is that?" Other observers have complained that DOE puts too much money into ani-

mal studies and not enough into long-term human studies. Says Robert Alvarez of the Environmental Policy Institute, "the only large populations that have been studied are rats, fruit flies, and A-bomb survivors."

Environmental groups are not the least bit mollified by DOE's recently announced plans to have Johns Hopkins University conduct an enormous study of the effects of radiation on the health of 250,000 current and past employees of seven shipyards around the land. It will go back to the 1950's, when they first started putting nuclear power plants in boats, and is supposed to take 2 to 5 years. Ruth Clusen, DOE's assistant secretary for environment, extolled the study as "the largest study of its kind ever undertaken" and proudly noted that Johns Hopkins was above suspicion, having "no previous relationship" with DOE. Chief investigator Genevieve Matanoski explained that it was an "ideal study" because the total exposed population of 90,000 could be matched with an unexposed control group who otherwise had exactly the same sorts of jobs.

Nonetheless, the study has been widely criticized. On 15 March the machinists' union sent a letter to 71 members of Congress accusing the DOE of "tenuous" motivations, criticizing the shipyard study as duplicative and of questionable value, and reiterating its demand that Mancuso be allowed to complete his project.

The DOE study has been called redundant because NIOSH is already busy expanding and analyzing data on one of the installations, Portsmouth Naval Shipyard, that were originally collected by Boston epidemiologist Thomas Najarian (Johns Hopkins will be feeding the NIOSH information into its own study). Mancuso calls the DOE project a "diversionary study" which may "convey the misleading impression to the public that you have to wait 20 or more years" for conclusive data when his data are already here. (He is assuming the study will be extended because 5 years is too short a time for significant findings. The two oldest shipyards, Portsmouth and Groton, have been installing nuclear power plants only since the late 1950's.)

Mancuso also says shipyards are not a very good choice because there are more toxic and carcinogenic materials to distort the findings at a shipyard than at an energy facility. What's more, he says, there is no evidence that the radiation monitoring has been reliable. In short, the study represents to many, including Carl Z. Morgan, of the Georgia Institute of Technology, the "father of health physics," nothing more than a bid by the DOE to hang on to its near monopoly on health effects research.

Science tried to get the DOE side of the story from Liverman, an old-timer who has been intimately involved, but he refused to talk even over the telephone. Clusen, now his boss, told *Science* that all the arrangements are appropriate and proper. She has repeatedly dismissed concerns about conflict of interest on the grounds that her office is not involved in developing nuclear energy. If people persist in seeing such conflict, "that's in the eye of the beholder," she said.

The lines are less clearly drawn on another major institutional issue—regulation of radiation exposure. The Environmental Protection Agency (EPA) has responsibility for establishing the basic exposure limits, which have long stood at 5 rems for occupational exposure and 500 millirems for the general population (natural background radiation is 100 millirems). Responsibility for writing occupational regulations lies in many hands. The major agencies are the Nuclear Regulatory Commission (nuclear facility and certain nuclear materials workers), the Department of Defense (naval shipyards), the DOE (manufacture and assembly of nuclear weapons), the Labor Department's Occupational Safety and Health Administration (OSHA) (hospital x-ray technicians and industrial employees who use radiation in manufacturing processes), and Labor's Mine Safety Administration (uranium mining).

There is much sentiment in favor of centralizing regulatory authority in one agency. Some have recommended the creation of an expanded and more powerful version of the old Federal Radiation Council, whose responsibility for recommending exposure guidelines was transferred to EPA in 1970. There is considerable talk about centralizing all occupational-regulation setting (including that for the military) in OSHA, but this would meet opposition from DOE and DOD, many of whose nuclear activities are closely entwined and who like to run their own show.

The EPA, which in the past "has been fought tooth and nail by AEC and ERDA," according to an EPA official, may need additional support in exerting its authority over environmental radiation exposures—that is, exposures for the general public. The agency is getting a gradually expanded purview—in 1978 Congress told it to regulate radioactivity in the air, which puts it in potential conflict with the NRC—but it had to fight hard recently to put through a standard limiting environmental emissions from facilities in the nuclear fuel cycle to 25 millirems.

The substantive question, of course, is whether the 5-rem exposure limit is safe. The DOE says it is. The HEW Interagency Task Force says that there is not yet any evidence indicating that it should be lowered. Mancuso thinks it should be lowered by a factor of 10 (bringing it in line with the exposure limit for the general population). Morgan thinks the limit should be cut in half for now, as a more drastic reduction would kill the nuclear power industry.

Differing risk estimates arise from the fact that scientists are split three ways over the "linear hypothesis," which postulates that the dose-response relation based on findings at high doses of radiation can be extrapolated in a straight line to predict risks from low doses. Before the first BEIR report was issued in 1972, many thought that linear extrapolation overestimated the risk of low-level radiation—that is, they believed there was a threshold below which there would be no ill effects. Now most experts tend to accept the linear hypothesis. But there are a number of scientists who lean in the opposite direction—toward the belief that the linear hypothesis underestimates low-dose risks. Mancuso is the chief proponent of this view.

Although the debate over allowable exposure has often been couched in terms of what is an acceptable risk in view of the benefits to be gained from radiation, Robert Minogue, commissioner at the NRC, makes a telling point: "What's conservative is not self-evident." If the linear hypothesis understates the risk, then lowering the limit could be unwise because it would result in more people being exposed to low-level radiation because more people would be required to do the jobs that entail such exposure. On the other hand, if the hy-

"When you say when will we get an answer . . . that is tantamount to saying when will we have an answer to cancer."

pothesis *overstates* the risk (as some pronuclear advocates believe) "we should lower the standard right now because that implies a quasi-threshold" beneath which there would be no detectable risk.

This is the sort of stuff that will be grappled with this summer when the EPA, NRC, and OSHA hold hearings to reevaluate radiation protection standards. Everyone is still waiting for the latest BEIR committee report to supply risk estimates.

An issue that has been riding along on a separate track from the occupational exposure debate is the matter of medical radiation. X-rays are on the increase, although the patterns of use have changed somewhat since the 1950's. Twenty years ago x-rays were used routinely for treatment of benign conditions such as acne, ringworm, and tonsillitis. Research since then has linked low doses of x-rays with increased risk of cancer. One major finding was made by Alice Stewart of Birmingham University, England, who is now working on the Mancuso project. In the "Oxford survey" she established that children whose mothers had been given low-dose diagnostic x-rays showed a higher incidence of leukemia and other cancers. Other studies have linked thyroid tumors with stray radiation—amounting to perhaps 6 or 7 rads—from high doses used to treat ringworm.

Estimates of how much unnecessary diagnostic radiography is going on vary widely. Ralph Nader has said 50 percent is unnecessary; Otha Linton of the American College of Radiology says the figure may be more like 10 percent. The FDA's Bureau of Radiological Health says maybe 30 percent. Superfluous exposures result from many things—faulty or outdated equipment, bad clinical judgment, bad training, pressure by patients, and fear of malpractice suits.

It is well to note that although x-rays are on the increase, the average diagnostic dose is now a fraction of a rad, three or four times less than it was 20 years ago. Better equipment, faster film, electronic image intensification, and more sophisticated use of the technology are responsible. A mammographic breast examination used to deliver several rads—now most exposure has been reduced to less than 1 rad.

Nonetheless, since medical radiation accounts for 90 percent of man-made radiation, the pressure is on to reduce it. The FDA since 1974 has issued standards of performance for x-ray equipment but has no say over its use. There has been considerable discussion about the desirability of requiring licensing for x-ray technicians—at present only three states have active licensing programs. The HEW Task Force, in view of the paucity of federal leverage, has recommended a vast public education program and the development of model guidelines for accrediting technicians and standard dosages for x-ray examinations.

The amount of medical radiation seems very high in comparison with the occupational dose limit, particularly in view of the fact that more than half the population of the United States is x-rayed in any given year. Linton, however, says the two types of exposure are not readily comparable because the circumstances, timing, and energy levels and characteristics of the radiation are all different. Besides, a medical x-ray is a calculated risk designed to benefit the subject and not a gratuitous dose.

Questions surrounding hazards of low-level radiation are as important as they are tedious because their resolution is essential in redefining the limits of all radiation technologies. Sharper answers will also have to be found if the issue of government compensation for allegedly radiation-caused illness is ever to be settled. So far only a handful of awards have been made to veterans, shipyard workers, and uranium miners. Reducing the occupational exposure limit would weaken the government's defense against claims and against lawsuits such as those now shaping up against the DOE. Last September, 35 Utah cancer victims and their families initiated claims for damages, alleging government negligence in the conduct of bomb tests in the 1950's. The number of claimants, all of whom live in a 90-degree arc around the Nevada Test Site—the same area in which increased rates of leukemia among children have been found—has now grown to 500.

Cancer is, so to speak, the bottom line when it comes to health effects of radiation. There are many other effects, including genetic damage and alterations to the immune system, but these disorders would be extremely difficult to trace to radiation. Another imponderable, about which research has yielded little information so far, is the extent to which various toxic and carcinogenic substances interact synergistically with radiation. So complex are the variables that a colossal amount of research is required to achieve even a small reduction of uncertainty. As an EPA official put it, "when you say when will we get an answer to this question, that is tantamount to saying when are we going to have an answer to cancer."

—CONSTANCE HOLDEN

Research News

Low-Level Radiation: Just How Bad Is It?

The controversy over the effects of low-level radiation has been sparked by several recent—but highly disputed—studies

If a number of recent reports are right, the harmful effects of low doses of radiation may be substantially—perhaps 10 times—greater than previously estimated. These reports, which fly in the face of the conventional view of the dangers of low-level radiation, have added new fuel to the ongoing controversy over the adequacy of the standards set by the U.S. government to regulate medical, occupational, and environmental exposures to radiation.

The radiation hazard most people are concerned about is cancer, although other untoward effects, such as genetic damage that may produce birth defects in future generations, are also possible. The current radiation standards are based on estimates of cancer risk derived from studies of some 82,000 survivors of the atom-bomb attacks on Hiroshima and Nagasaki and of groups of people who received therapeutic x-ray treatments for a variety of conditions.

Many of these individuals, especially those treated with the medical x-rays, received relatively high doses of radiation usually delivered in one or a few exposures. This situation is very different from that of most environmental and occupational exposures where low doses are received gradually over an extended period of time. Consequently, there has been a long-standing debate about how best to extrapolate data on risk estimates obtained at high doses to the lower doses likely to be encountered in the normal course of life.

This kind of low-level radiation is not precisely defined but is usually taken to mean exposures of less than 5 to 10 rems annually. The rem, or roentgen equivalent man, is a common unit for measuring radiation dose. It refers to the amount of radiation required to produce a particular amount of biological damage in tissue. The rad is another unit of radiation measurement; it specifies the amount of energy absorbed by tissue. For the type of radiation designated low LET (for linear energy transfer), including x- and γ-rays, the rad and rem are roughly equivalent. High LET radiation, such as the α-particles released by plutonium-239 and fast neutrons, is more effective than low LET radiation at causing tissue damage. Thus, for high LET radiation, 1 rad may be equivalent to as many as 20 rems.

The data on radiation risks obtained from the atom-bomb survivor study suggested two possible ways in which the data on cancer incidence at high radiation doses might be extrapolated to low doses. For high LET radiation, the risk seemed to decline with dose in a linear fashion with zero risk at zero dose (the solid line in Fig. 1). For low LET radiation, the risk seemed to fall off more quickly at low doses, as illustrated by the dashed line in Fig. 1. Thus, the assumption was made that the linear extrapolation would be conservative because it would overestimate the risk of low levels of some kinds of radiation. Maximum permissible exposures set according to these risk estimates would then be, if anything, lower than they have to be to safeguard the public health.

What some researchers are now saying, however, is that the linear extrapolation is not conservative after all. Rather, the risks at low levels of radiation are much greater than linear extrapolations would indicate.

The new data come from epidemiological studies of human beings exposed to low doses of radiation from medical x-rays, on-the-job exposures, and the fallout from nuclear weapons testing. For the most part the doses are well within those permitted by current standards.

In fact, the investigators calculate doubling doses for some forms of cancer to be as low as 5 to 15 rems. (The doubling dose is the amount of radiation that will double the cancer incidence.) These values are only about one-tenth or less of those predicted by the atom-bomb survivor study. Moreover, they are in the same range as the maximum occupational exposure now permitted by government standards. This is 5 rems per year for external radiation, an adequate standard according to the earlier risk estimates—but far too high if the newer estimates are correct.

Not everyone is convinced that the new estimates are valid, however. Some epidemiologists have severely criticized the design and data analyses of the studies producing them. The question of who is right is not going to be easy to resolve.

The experts are certainly having trouble agreeing on the magnitude of the hazards of low-level radiation. The dilemma has been plaguing the Committee on the Biological Effects of Ionizing Radiation of the National Academy of Sciences.* The BEIR committee has been reviewing the data to determine whether revision of the risk estimates the committee produced in its 1972 report is required. The committee is reported to have had trouble agreeing on a recommendation, although there are rumors that it will propose a reduction in permissible occupational exposures. Edward Radford of the University of Pittsburgh, committee chairman, is already on record in congressional testimony as being in favor of a tenfold reduction. The BEIR committee report, which was due in December of 1978, is expected to be released soon.

In May 1978, the White House commissioned an Interagency Task Force,† under the leadership of the Department of Health, Education, and Welfare, to

*The members of the BEIR committee are: Edward Radford (chairman), University of Pittsburgh; Seymour Abrahamson, University of Wisconsin; Gilbert Beebe, National Cancer Institue; Michael Bender, Brookhaven National Laboratory; Bertrand Brill, Vanderbilt University School of Medicine; Reynold Brown, University of California; Stephen Cleary, Medical College of Virginia; Cyril Comar, Electric Power Research Institute; Carter Denniston, University of Wisconsin; Jacob Fabrikant, University of California School of Medicine, San Francisco; Marylou Ingram, University of Miami School of Medicine; Charles Land, National Cancer Institute; Charles Mays, University of Utah Medical Center; Dade Moeller, Harvard School of Public Health; Dean Parker, Austin, Texas; Harald Rossi, Columbia University College of Physicians and Surgeons; Liane Russell, William Russell, and Paul Selby, Oak Ridge National Laboratory; Margaret Sloan, National Cancer Institue; Edward Webster, Massachusetts General Hospital; Henry Wellman, Indiana University School of Medicine.

†The members of the Interagency Task Force on the Health Effects of Ionizing Radiation are: F. Peter Libassi (chairman), Department of Health, Education, and Welfare; Donald Fredrickson, Director, National Institutes of Health; William Foege, Director, Center for Disease Control; Arthur Upton, Director, National Cancer Institute; Donald Kennedy, Commissioner, Food and Drug Administration; Linda Donaldson and June Zeitlin, HEW; Gilbert Beebe and Charles Land, National Cancer Institute; Clark Heath, CDC; John Villforth, FDA; Vice Admiral Robert Monroe, Department of Defense; Ruth Clusen and James Liverman, Department of Energy; Robert Copeland, Department of Labor; David Hawkins and William Mills, Environmental Protection Agency; Robert Minogue and Karl Goller, Nuclear Regulatory Commission.

formulate a program for addressing the questions raised about the effects of low-level radiation and the protection of the people who are exposed to it. The "working papers" of the Task Force released for public and scientific comment on 27 February serve to illustrate the problems faced by the BEIR committee. One conclusion of the Task Force states: "Current data are obviously insufficient to settle the question of human low-dose effects." Nevertheless the group points out that data from some recent studies are suggestive of higher than expected risks. The Task Force recommends further study but does not now see a need to reduce the occupational radiation exposures permitted by governmental standards.

One of the studies suggesting that low-level radiation entails a high risk of cancer is being carried out by Thomas Mancuso of the University of Pittsburgh and Alice Stewart and George Kneale of the University of Birmingham (England). To say that their conclusions are controversial is an understatement.

These investigators have been analyzing the causes of death of people who had worked at the U.S. government's nuclear facilities in Hanford, Washington. The workers were exposed to radiation delivered at very low dose rates over an extended period of time.

According to Mancuso, Stewart, and Kneale, 6 percent of the cancer deaths of the Hanford workers were caused by the radiation to which they were exposed. Moreover, these deaths were mostly due to cancers of tissues, such as the bone marrow, pharynx, lung, pancreas, and large intestine, which have been classified as being very sensitive to radiation by the International Commission on Radiation Protection.

Mancuso, Stewart, and Kneale estimate that the dose of radiation required to double the incidence of multiple myeloma (a cancer of the bone marrow) is only about 4 rads. For cancers of the lung, large intestine, and pancreas, they calculated the doubling dose to be about 14 to 15 rads.

Mancuso first began to study the Hanford workers in 1964. At that time the Atomic Energy Commission, whose research-related activities have since been incorporated into the Department of Energy, funded the work. But DOE withdrew its financial support in 1977 on the grounds that Mancuso's execution of the study was defective. Many people, including Mancuso, viewed DOE's action as an attempt to suppress findings unfavorable to the department's policies that encourage the development of nuclear

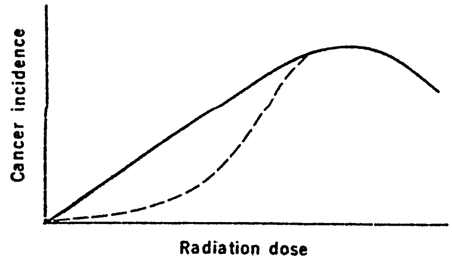


Fig. 1. Graph showing two possible ways in which the incidence of cancer might increase as the radiation dose increases. Both curves eventually level off and then decrease at high doses of radiation that kill cells rather than causing them to become cancerous.

power plants. The Environmental Policy Center, a privately funded environmental action group in Washington, D.C., now provides much of the support for the joint efforts of Mancuso, Stewart, and Kneale.

Researchers in England and this country have lodged vigorous criticisms of the conclusions reached by these three investigators. The critics question the low doses at which they are finding adverse effects of radiation and the lack of an increased incidence of leukemia in their study. Most other investigations have linked radiation to the development of leukemia, a finding not duplicated in the questioned study at the present stage of analysis.

The critics think the conclusions of Mancuso, Stewart, and Kneale are wrong because the statistical methods they used to analyze the Hanford data are defective. For example, Charles Land of the National Cancer Institute (NCI) with George Hutchison and Brian MacMahon of the Harvard School of Public Health and Seymour Jablon of the National Academy of Sciences have reanalyzed the Hanford data with a conventional method for doing studies of this type; they found only an increased incidence of multiple myeloma and pancreatic cancer. Another analysis of the Hanford data by Sidney Marks and Ethyl Gilbert of DOE's Battelle Pacific Northwest Laboratory and B. Breitenstein of the Hanford Environmental Health Foundation, also a part of DOE, produced similar results.

Although Mancuso cites these findings as confirming at least part of the conclusions reached by him and his collaborators, Land has another opinion. He says the size of the Hanford population is too small to give reliable results on cancer incidences. In other words, the apparent increases in multiple myeloma and pancreatic cancer might merely be statistical flukes that would disappear if a large enough population were studied. By Land's estimate, a population of 1 to 10 million would be needed. The total Hanford population includes about 35,000 workers.

Even if the increases in the cancers are real, they may not be radiation effects, according to Land, who says there may be alternative explanations for the excess cancers. Multiple myeloma and pancreatic cancer are known to be caused by other industrial pollutants to which the Hanford workers may have been exposed. Mancuso maintains, however, that the Hanford workers' environment is relatively free of occupational carcinogens other than radiation.

If the criticisms of the conclusions of Mancuso, Stewart, and Kneale have been vigorous, so have their replies to that criticism. According to Mancuso, the issue is not so much the size of the sample but rather whether the appropriate statistical method was used to analyze what is happening to the population. The method used by statistician Kneale to determine the effects of radiation on the Hanford workers is capable of doing the job, at least in the view of his colleagues in that study. Kneale originally thought that he had developed a new method for the Hanford study, but when he submitted it for publication to the journal *Nature*, he learned that his procedure was a variation of one previously developed by B. D. Cox of Oxford University for measuring the beneficial effects of drugs. As Kneale told a reporter for *Nucleonics Week* (15 February 1979, pp. 12-13), "We have simply reversed the process to see how much harm is caused by a dose of radiation instead of calculating how much good a drug might do."

Stewart says they have now reanalyzed the Hanford data, taking into account the criticisms of their earlier work, and have found the same results. She thinks that the critics have been concentrating their attacks on that earlier analysis, which was somewhat preliminary in nature, but that the more recent analyses have answered all the questions the critics raised.

Stewart herself is highly critical of the atom-bomb survivors study, which she maintains has underestimated the incidence of radiation-induced cancers. She points out that the study did not begin until 1950, 5 years after the bombs were dropped. Immediately after the blast, conditions would have been such as to cause the selective deaths of the weaker members of the population, who are usually concentrated in the cancer-prone age groups. Therefore, Stewart concludes, following an atomic explosion, many of these cancer-prone in-

dividuals may have died of causes other than cancer before their malignancies became apparent. Other work has shown that people who are developing cancer, especially leukemia, which was the first cancer to develop in excess among the atom-bomb survivors, are more susceptible to other causes of death. No evidence suggesting an increased death rate from causes other than cancer in the atom-bomb survivors has turned up, however.

Stewart also suggests a reason why leukemias were so prominent among the atom-bomb survivors and not among the Hanford workers. Atom-bomb blasts produce a lot of radioactive dust that may be inhaled and ingested. Thus, Stewart thinks that the leukemias, which developed early in the survivors, may have resulted from such internal radiation, whereas the solid tumors, which developed later, may have resulted from the external radiation. The Hanford workers have not been exposed to radioactive dust the way the atom-bomb survivors were.

Another indication that low-level radiation encountered on the job may cause cancer comes from a preliminary study of the causes of death of men who worked at the Portsmouth Naval Shipyard where nuclear submarines have been repaired and refueled since 1959. The study, which was carried out by Thomas Najarian, a physician who was then at the Boston University School of Medicine, Theodore Colton of Dartmouth Medical School, and a group of reporters from the Boston *Globe*, suggested that there was an excess of cancer deaths among shipyard workers who had contact

The Sources of Ionizing Radiation

Natural sources account for much—about 50 percent—of the radiation to which the general population of the United States is exposed, according to the Environmental Protection Agency. Little or nothing can be done to minimize exposure to this natural background radiation, roughly one-third of which is in the form of cosmic rays coming in from outer space. The remainder originates in sources such as deposits of minerals, including uranium and phosphate ores, that contain radioactive components. Some of the radioactivity may turn up in common building materials, granite and brick, for example, or may make its way into our air, water, and food supplies. But the average exposure to an individual from natural radiation sources is very low, a total dose of about 0.1 to 0.2 rem per year.

Medical and dental procedures constitute the next largest radiation source; they contribute about 40 percent of the total exposure of the general population. Most of this comes from the use of diagnostic and therapeutic x-rays, with the remainder attributed to the use of radiopharmaceuticals. Radiopharmaceuticals concentrate in specific organs and give physicians information about the clinical condition of those organs.

Medical and dental radiation is the largest block of radiation subject to human control. Although its use is generally considered to provide benefits that outweigh the risks, Health, Education, and Welfare Secretary Joseph A. Califano has recently directed the Food and Drug Administration to accelerate its program to reduce unnecessary exposures to medical and dental radiation in order to minimize the risks as much as possible.

1978 Estimates of the radiation exposures of the U.S. general population. [Data on radiation exposures as summarized by the Interagency Task Force on Ionizing Radiation]

Source	Person-rems* per year (in thousands)
Natural background	20,000
Healing arts	17,000
Technologically enhanced	1,000
Nuclear weapons	
Fallout	1,000 to 1,600
Development, testing, and production	0.165
Nuclear energy	56
Consumer products	6

*"Person-rems" are calculated by multiplying the total number of people exposed by their average individual doses in rems.

Radioactive fallout from nuclear weapons tests is the third largest source of radiation exposures, but it represents only about 3 percent of the total. Most of the fallout produced by U.S. weapons occurred between 1945 and 1962 when the testing was carried out in the atmosphere. Since the Atmospheric Test Ban Treaty of 1963 went into effect, the United States and the Soviet Union have tested their weapons underground. These tests have released little fallout into the atmosphere. But some of the radioactive materials in fallout, including strontium-90 and plutonium isotopes, are extremely long-lived. Materials released from the atmospheric tests are still present in the environment and in our bodies. Moreover, some countries, notably China and India, still occasionally conduct weapons tests in the atmosphere. The doses of radiation received from fallout vary with geographical location. People living immediately downwind from the test sites usually get the largest doses, but weather patterns can carry the radioactive materials for long distances and they are now spread over the entire globe.

Although the average exposures of the general U.S. population from natural radiation sources are very small, human activities can greatly increase the exposures of specific groups of people. The activities include the mining and processing of ores, uranium oxide, for example. Miners and other workers carrying out these activities and people living near the mines and processing plants are exposed to higher radiation doses than the general population. This "technologically enhanced natural radiation" accounts for about 2.5 percent of the total human exposure in this country.

Another source of radiation exposure is the use of nuclear energy to produce electricity. Most of this exposure is concentrated in the workers producing the nuclear fuels and running the power plants. People living near such facilities are exposed to lesser doses.

Finally, some consumer products emit very low levels of radiation. They include luminescent clock or watch dials containing radium, some kinds of smoke detectors, color televisions, and the glass used for making eyeglasses.

—J.L.M.

with nuclear materials. The investigators did not have reliable estimates of radiation doses for the shipyard workers, however. In fact, they determined whether the dead workers had been exposed to radiation by asking the next-of-kin.

In a move that is itself the subject of some controversy because of the conflict-of-interest allegations lodged against DOE by Mancuso and others, the department has recently announced a large-scale follow-up study of workers in seven shipyards where nuclear work has been done. The investigation, which is being contracted out to researchers at Johns Hopkins University, will take 5 years and cost almost $10 million.

But Mancuso says that 5 years and $10 million will not be adequate to do the job. Since most nuclear shipyards are relatively young, and the latent period for cancers may be 15 to 20 years or more, an adequate study could take 20 years to accomplish. A shorter study might give false negative results if it were stopped before an increase in cancer incidence became apparent.

Occupational exposures are currently a potential problem for perhaps a few hundred thousand workers, a substantial number, but still a small fraction of the population exposed to the most important source of man-made radiation, that of medical and dental x-rays. According to a survey performed by HEW, 60 percent of the U.S. population had at least one such x-ray in 1970. The use of medical and dental x-rays has probably increased since then.

Recently, Irwin Bross and his colleagues at Roswell Park Memorial Institute published results implicating diagnostic x-rays as a significant cause of cancer and even heart disease. Bross's study is also controversial. The editor of the *American Journal of Public Health*, which published the study in the February issue, took the unusual step of running a disclaimer to the effect that "Dr. Bross stands virtually alone in defense of his data and the interpretations he places on them." The journal published the report because "Dr. Bross has been a respected investigator whose statements are frequently quoted by the press, and because published critiques of his analysis have been rare. . . ." Accompanying the Bross article is a critical review by Land and John Boice, also of NCI.

According to Bross, his study is the first to show directly how the incidence of leukemia increases as the radiation dose increases from 0.1 to 10 rads. The men studied had been exposed to ordinary diagnostic radiation in this dose range. Other studies of the effects of

Fig. 2. Photograph of a mushroom cloud produced by an atmospheric nuclear bomb test. The cloud extended well into the stratosphere, with the mushroom cap spreading about 100 miles. (Source: United States Air Force)

medical x-rays have involved much higher doses and the data had to be extrapolated to the lower dose levels.

Bross now estimates that the risk of the low-level radiation is some ten times greater than the previous studies predicted. In particular, he believes that some portions of the population are especially sensitive to radiation effects.

The source of Bross's data is the Tri-State Survey, a survey of leukemia cases in sample areas of New York, Maryland, and Minnesota. Bross says that even the large population included in the Tri-State Survey is too small for detection of radiation hazards by standard statistical methods. For this reason, he and his colleagues developed a new technique for analyzing the data.

According to Boice and Land, however, this new statistical method is not a valid way of analyzing the data. They detail their objections to it in their article in the *American Journal of Health Physics*.

One of their many criticisms concerns the increased susceptibility of individuals who are developing leukemia to infections and other health problems. Such individuals come under increased medical surveillance, including the use of medical x-rays. Thus, even though the x-rays may precede the diagnosis of leukemia they do not necessarily cause the blood cancer. In reply to this criticism Bross says that most of the x-ray exposures occurred at least 3 years before the onset of leukemia, a time when the early effects of the condition would not yet be developing.

A third source of low-level radiation exposure, in addition to occupational and medical sources, is contamination of the environment with radioactive materials. Among the sources of the contamination are fallout from nuclear weapons tests (Fig. 2) and various nuclear facilities such as plants for processing reactor and weapon fuels.

According to Carl Johnson of the Jefferson County Health Department in Lakewood, Colorado, a large area of land in Jefferson County has been contaminated with radioactive plutonium, which was released from the Rocky Flats Nuclear Weapons Plant. The contaminated region, which is near Denver, is highly populated. Almost 150,000 people live within 10 miles downwind of the Rocky Flats plant.

Some of the release was the result of emissions of permissible quantities of plutonium, but most of it occurred as a result of a fire at the plant in 1957 and because of leakage from barrels of contaminated oil stored by the plant. Johnson says the plutonium concentrations in some parts of Jefferson County are more than 3000 times higher than the background plutonium concentrations produced by nuclear fallout. Some plutonium isotopes are extremely long-lived; plutonium-239, for example, has a half-life of 24,000 years.

Johnson now finds higher incidences

of cancer among people living in the contaminated areas. He obtained his cancer incidence data from the Third National Cancer Survey conducted between 1969 and 1971 under the aegis of NCI. Johnson says there appears to be a direct association between the plutonium concentrations in the soil and the increased risk of cancer. The increases in cancer incidences ranged from 6 percent in the areas with the least contamination to 16 percent in the area with the most contamination. Among the cancers showing increases were leukemia, lung cancer, and cancer of the nasal passages and larynx. Johnson thinks that inhalation and ingestion of plutonium in dust are the most likely routes by which the material enters the body. Jefferson County is a dusty, arid region having only about 8 inches of rainfall per year.

Johnson points out that the plutonium concentrations in most of the contaminated regions are still only about one-hundredth of the maximum permissible concentration proposed by the Environmental Protection Agency for limiting plutonium contamination in residential areas. Johnson has written EPA Administrator Douglas M. Costle to request a public hearing on the adequacy of the proposed standard. The EPA has declined this request on the basis of its having held a public meeting on the issue last year in Colorado.

Two studies have now implicated radioactive fallout as a cause of an increased risk of cancer, primarily leukemia. One study was carried out by investigators at the Center for Disease Control in Atlanta. It includes more than 3100 men who participated in 1957 in a nuclear weapons test code-named "Smoky." Most of the men at the Smoky test were exposed to less than 5 rads of external radiation, according to the exposures monitored by their film badges.

Analysis of the data is not yet complete but so far eight cases of leukemia have been found. Fewer than four would be expected in a group of men of that size and age range. Glyn Caldwell of the CDC, who is in charge of the study, considers this finding to be suspicious, but he cannot be sure about its significance until all the data are analyzed.

The second study includes children living in Utah who were exposed to the nuclear fallout from weapons tests conducted in the Nevada desert between 1951 and 1958. Joseph Lyon and his colleagues at the University of Utah College of Medicine compared the leukemia death rates in the parts of Utah that received high fallout doses with the rates in areas of the state subjected to little fallout. The rate did not change in the low-fallout regions between 1944 and 1975 but it more than doubled in the high-fallout areas between 1959 and 1967. After that it declined to about the same value it had been before the weapons tests began. The findings imply that the radioactive fallout caused a temporary rise in leukemia deaths in the high-fallout counties of Utah.

According to Land, who has been spending a lot of time recently in commenting on epidemiological studies linking cancer to low-level radiation, the interpretation of Lyon's data may not be as simple as it seems. Lyon's results show that the death rate from childhood leukemia in the high-fallout counties was much lower both before the weapons tests and in the period from 1968 to 1975 than it was in the low-fallout regions. Moreover, the death rate from childhood cancers other than leukemia declined after the nuclear tests at a time the leukemia death rate was rising, so that the death rate from all forms of childhood cancer was unchanged. All this implies that the high leukemia death rate observed by Lyon between 1959 and 1967 might be a statistical fluke, although Lyon points out that, at its peak, the rate was still some 50 percent higher than the rate in the low-fallout counties and in the United States as a whole.

Some necessary information is also missing from this study. No one really knows how much radiation the children were exposed to. Thus Lyon says it is impossible to tell whether the increased leukemia death rate was an unusually large response to low-level radiation or whether the exposures were actually high. At least one test resulted in heavy fallout in the area of St. George, Utah, which is in Lyon's high-fallout area, when the wind shifted unexpectedly at the time of the test. Lyon hopes that newly released information on the nuclear tests will provide the data needed to assess the doses of radiation to which the people of Utah were exposed.

Investigators have known for some time that radiation, usually in relatively high doses, can cause chromosome abnormalities. Now there are indications that workers exposed to low-level radiation within the limits set by government standards can also experience the abnormalities. A group of researchers at Western General Hospital in Edinburgh, consisting of H. J. Evans, K. E. Buckton, G. E. Hamilton, and A. Carothers, identified an increased number of chromosome aberrations in nuclear-dockyard workers. Most of the dockyard workers were exposed to less than 5 rems per year over a period of 10 years.

In addition, William Brandom of the University of Denver and his colleagues found increased numbers of abnormal chromosomes in workers at Rocky Flats, even in men whose bodies contained concentrations of plutonium well within the amounts permitted.

What some researchers are now saying is that . . . the risks at low levels of radiation are much greater than linear extrapolations would indicate.

The biological consequences of the abnormalities found in the two studies is unclear. There is general agreement, however, that damage to the genetic material carried in the chromosomes is undesirable even if the exact effects of that damage are not understood.

Because of the results of the studies linking cancer and chromosome damage to low-level radiation, some researchers and members of environmental groups are now recommending an immediate reduction in permissible levels of radiation exposures. However, many investigators, in and out of government, maintain that, because of their flaws, these studies are not conclusive, either separately or in combination. As Arthur Upton, Director of the NCI, puts it, "Fragmentary and incomplete data do not by sheer numbers make a case." Not surprisingly, Mancuso has a different view: "When a series of independent studies point in the same direction, the evidence should not be ignored."

Or, as one might say, where there is smoke there is fire. If nothing else, the new data are forcing a reexamination of the risk estimates on which radiation standards are based. Since every man, woman, and child in the country is exposed to some kind of man-made radiation at some time in their lives, a reevaluation of those risk estimates, however messy it may be in execution, certainly appears to be in order.—JEAN L. MARX

Nuclear Waste Disposal: Alternatives to Solidification in Glass Proposed

But glass is still seen as a reasonable solution in the interim

More than a quarter-million cubic meters of liquid radioactive wastes, a volume equivalent to that of about 200 olympic swimming pools, are now being held at government installations awaiting final disposal. More of these highly radioactive wastes will inevitably be generated by nuclear bomb production and possibly by reprocessing of spent fuel from commercial nuclear power plants if President Carter's indefinite ban on reprocessing is ever lifted.

The disposal of radioactive wastes is receiving considerable attention in both political and scientific circles as an important factor in the public acceptability of nuclear power. Waste management is the subject of a study by the President's Interagency Review Group and is being examined during congressional hearings and numerous scientific meetings. The idea that disposal of long-lived, highly radioactive wastes needed only a little engineering to be practical has given way to widespread critical review of the technical problems involved, among them the selection of a suitably stable solid form for the wastes. Although glass, the traditionally favored waste form, has not held up well in recent tests of its durability, most experts still regard it as a reasonable alternative provided that the weaknesses recently pointed up by researchers are taken into consideration in the design of the waste disposal system. Materials scientists are now eager to show that improved waste forms, which by themselves could give confidence in a disposal system, can be developed.

During the past 20 years, the disposal plan of choice has been to incorporate the 40 to 50 radioactive elements dissolved (and suspended) in liquid wastes into blocks of glass, seal the glass in metal canisters, and insert the canisters into deep, geologically stable salt beds. Thus, the chemical form of the waste (the glass), its container, and the geological formation would provide three separate barriers to the release of the wastes until its radioactivity dies away some thousands to hundreds of thousands of years from now, depending on the character of the element.

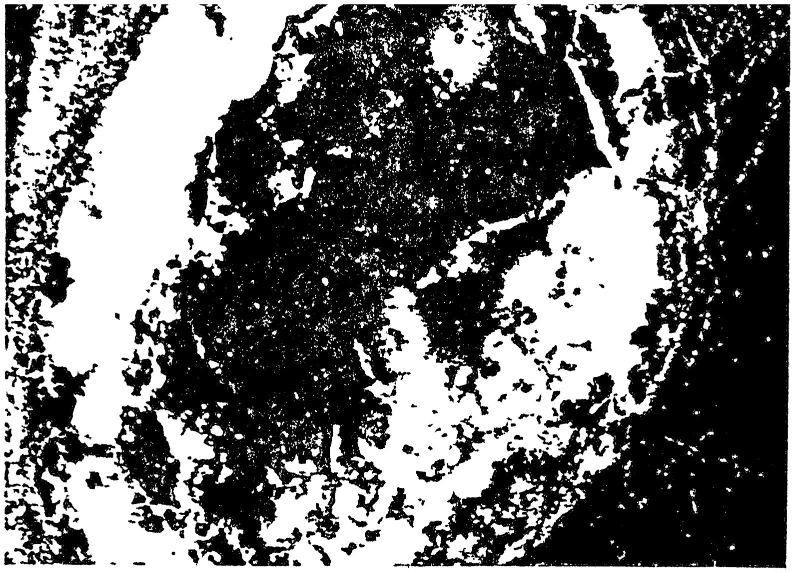
Over the last few years, some geologists and materials scientists have become concerned that perhaps not enough is known yet about the interaction of waste, container, and salt (or any rock) to have a reasonable assurance that the hazardous wastes will be contained successfully (*Science*, 9 June 1978, p. 1135). Recently, particular attention has been drawn to the idea that ceramics, crystalline materials resembling in many ways natural rocks, may be possible improvements over glass. A recent National Academy of Sciences report was critical of the past emphasis on glass and drew attention to the promise of ceramics (*Science*, 18 August 1978, p. 599). The Department of Energy also wants a closer look at the subject. It has requested an increase in funding for the evaluation of alternatives to glass from the $6.5 million spent in fiscal year 1978 to about $13 million requested in the budget for fiscal year 1980.

Ceramics, if sufficiently stable, might constitute a significant improvement over glass.

Glass has received the most attention in the United States and abroad because it has a number of desirable chemical and physical properties and because the technology for producing massive blocks of it has been readily available from industry. All glasses are amorphous, having no regular order in the arrangement of their atoms; but these atoms (in large part silicon, boron, and oxygen) are strongly bonded to one another in a single, continuous, three-dimensional structure. Having no strict organization on the atomic level, glasses can accommodate a variety of different elements. Doubly and triply charged positive ions (cations) become part of the network itself, and singly charged cations are less securely trapped in the glassy structure. Leaching of radioactive elements from this structure by water has been shown to be low at moderate temperatures. Leaching by water is the primary concern at any disposal site because moving water could carry the wastes beyond the repository before all the radioactivity had decayed. Another advantage of glass is thought to be its inherent resistance to structural damage from radiation and the increased leaching that would likely result.

The biggest advantage of glass at present is the demonstrated practicality of producing large, highly radioactive blocks of it. Workers at Battelle's Pacific Northwest Laboratories (PNL) recently melted calcine, the product of spray-drying liquid wastes, and glass-making materials together to make a cylinder 2.4 meters by 20 centimeters of vitrified commercial reactor wastes, the first to be made on such a scale in this country. The French, at Marcoule, already have a vitrification plant operating on a routine industrial basis, although the wastes there are not as highly radioactive as those in the PNL glass. Waste ceramic processing is still on a small scale in the laboratory.

The suitability of glass under some of the more severe conditions anticipated for waste repositories has been questioned following recent tests of waste glass durability at high temperatures in water. In one set of such tests, Gregory McCarthy and his group at Pennsylvania State University placed a small sample of a borosilicate waste glass, developed at PNL, under 300 atmospheres of pressure at 300°C in distilled water. The glass contained nonradioactive isotopes of waste products. After 1 week under these conditions, the 4-millimeter spheroid had cracked and was discolored in several zones (see figure). At the end of 2 weeks, the sample had broken into several fragments and seemed totally altered. Although 5 percent of the cesium, one of the waste elements of greatest concern, escaped from the glass and re-



A spheroid (about 2 by 4 millimeters) of borosilicate waste glass treated with water at 300°C and 300 atmospheres for 7 days. The light zone is altered glass and the dark interior zone is apparently unaltered glass. [Source: Materials Research Laboratory, Pennsylvania State University]

mained in solution, it was the only one among the most hazardous elements to remain in substantial quantities, according to McCarthy. When a bittern brine, the kind of solution most likely to contact vitrified wastes in a salt formation, was substituted for the distilled water, large percentages of all the important types of elements went into solution.

This leaching and alteration is much greater than that observed in water at 1 atmosphere between room temperature and 100°C, the conditions of most previous leaching studies. This surprised some people studying waste disposal, but those familiar with the properties of glass anticipated such results. John Mendel of PNL suggests that it has not been a matter of the failure of glass to perform as expected, but rather that more is now expected of a solid waste form.

Proposed waste forms are being subjected to much more severe conditions than in the past, but these conditions may not necessarily be typical of those in an actual repository. Although temperatures in a repository could be higher than 200°C during the first few hundred years because of the heat generated by the wastes, a temperature as low as about 100°C could be chosen. To do this, the wastes could be stored for several decades while their heat output decreased, less waste could be incorporated in each canister, or fewer canisters could be stored per hectare. The presence of some water, even in bedded salt, now appears inevitable, but much more attention is being given to beefing up the canister material's resistance to corrosion. Conceivably, the wastes could be protected from the water, at least during the thermal period. Nonetheless, there is a strong feeling among many materials scientists that glass can and should be improved upon.

The frontrunner as a successor to glass is ceramics, which are nonmetallic crystalline materials formed at high temperature, such as chinaware or natural minerals. An apparent advantage of ceramics is that they already have an ordered atomic structure, whose properties can be tailored to a particular waste element and to conditions of a specific disposal site. So far, not all ceramics have shown improved performance as compared to glasses, but some preliminary results have impressed many materials scientists.

McCarthy's group at Penn State, in cooperation with PNL, has been developing a ceramic tailored for waste disposal that they call supercalcine-ceramic. Before drying the liquid wastes, they add several elements selected to form specific minerals with the waste elements when the dried wastes are simply heated or heated and compressed. In high-temperature leaching experiments involving distilled water, supercalcine-ceramics have exceeded the performance of the PNL glass, allowing about 0.5 percent of the cesium to escape, according to McCarthy. But in a bittern brine, most of the minerals proved as unstable as the glass, releasing large fractions of the waste load into solution. Among the brine-resistant minerals, the Penn State group has suggested that monazite, a phosphate, may be particularly suitable as a host for the actinide elements, which are long-lived and highly toxic components of radioactive wastes.

At the Australian National University, A. E. Ringwood and his group are also following the tailored ceramic approach. They have emphasized that the best minerals for waste solidification may be those that have proved most stable under natural conditions over geologic time. In order to include only these specific minerals, the Australian group limits the proportion of wastes in the ceramic, called synroc (synthetic rock), to about 10 percent. In contrast, the high loadings of supercalcine-ceramic (up to 80 percent) determine to a large extent which minerals are formed.

The first version of synroc consisted of six minerals, compared with the nine of supercalcine-ceramic. Although all the phases withstood 1000 atmospheres at 600°C in water for 24 hours, only three of the minerals survived similar conditions in 1 percent sodium chloride solution, which is generally less corrosive than bittern brines. A second version of synroc, consisting principally of the three stable minerals from the first version (a hollandite, zirconolite, and perovskite) and spiked with three waste elements, suffered no significant alteration or leaching during a 24-hour experiment at 800°C in 10 percent sodium chloride, according to Ringwood. Only at 900°C and 5000 atmospheres did it begin to break down during a 24-hour experiment.

The stability of the cesium in the hollandite crystal structure is probably due to the physical trapping of cesium, Ringwood believes. Cesium is apparently trapped in atomic-scale tunnels formed by linked aluminum and titanium atoms behind plugs of firmly bonded barium atoms. Rustun Roy of Penn State has pointed out that this kind of molecular engineering is a particular advantage of ceramics.

However, ceramics are not without possible disadvantages. Although materials scientists regard the preliminary synroc and supercalcine-ceramic results as encouraging, possible stumbling blocks to the use of such synthetic rocks remain to be investigated. One problem is radiation damage—the disordering of the crystal structure by alpha particles and the recoiling atoms that ejected them. Another is transmutation, which is the substitution of a new chemical element in the structure when its progenitor decays radioactively. Mendel suggests that, on the basis of leaching tests of irradiated waste glasses, radiation does not significantly affect the rate of leaching from glass.

Laboratory experiments on the effects of radiation on proposed ceramic waste forms have not yet been done, but geologic samples may provide some clues. Certain minerals contain radioactive uranium and thorium and suffer damage to their crystal structures over great peri-

ods of time. At this time, various interpretations of the geologic record are being made. Ringwood and McCarthy argue that even heavily damaged minerals, or metamicts, can retain their uranium and thorium over millions of years although exposed to severe conditions. Rodney Ewing of the University of New Mexico agrees that natural metamicts may provide good analogs for radiation damage to synthetic rocks, but cautions that a broad survey will be required to sort out the effects of age, composition, crystal structure, and environmental conditions.

It is now obvious that some ceramics are more stable than glass under certain conditions. But how much more stable must ceramics be so as to constitute a significant improvement? An immediate goal of researchers is to compare glasses and ceramics loaded with the same amount of wastes under identical conditions. Then the laboratory results can begin to be incorporated into predictions of waste behavior in a respository. With such predictions, any improved stability due to the form of the wastes can be compared with other ways of achieving reliable long-term containment.

In addition to the chemical and physical properties of the waste forms themselves, researchers are increasingly interested in the form of the wastes after they are exposed to realistic geologic conditions. McCarthy's Penn State group has found that a waste element may be leached into solution only to become part of another solid that is more stable under the prevailing conditions. They exposed basaltic rock and spent nuclear fuel, a possible solid waste form if reprocessing is abandoned, to water under high temperature and pressure. One hundred percent of the cesium left the spent fuel, but 98.8 percent of it did not remain in solution at 200°C because it became tied up with aluminum silicates from the basalt in a new mineral, pollucite. The basalt also prevented any detectable dissolution of uranium, apparently by maintaining reducing conditions that kept the uranium in its highly insoluble reduced form.

Chemical effects of the surrounding rock might also significantly reduce the dissolution of waste elements in the first place. Larry Hench of the University of Florida, working with glass and various rocks in water, reports that the presence of some kinds of rock leads to partial protection of the glass from dissolution. Apparently, certain soluble chemical species from the rock bind to the exposed glass surface, shielding it from the solution. Although waste-rock interactions are only beginning to be investigated, it has become obvious that the solid waste form cannot be considered alone. In fact, positive elements of geologic materials might actually be designed into the repository by surrounding the solidified waste with an "overpack" of crushed rock or clay. This would be only one part of an engineered barrier between the waste form and the surrounding rock.

A sample of the mineral microlite that has been damaged by natural radiation from its own uranium and thorium. Chemical alteration (dark areas) has occurred along microfractures. The area shown is about 1 millimeter across. [*Source: Bryan Chakoumakos, University of New Mexico*]

Originally conceived as a single canister of stainless steel, possible engineered barriers now range from the microscopic to the massive. John Rusin of PNL, M. F. Browning of Battelle Columbus Laboratories, and McCarthy have coated 2-millimeter pellets of supercalcine-ceramic first with a 40-micrometer layer of carbon, to increase leach resistance, and then with a 60-micrometer layer of aluminum oxide, to increase oxidation resistance. After 4 weeks in a bittern brine at 400°C and 300 atmospheres, the coatings remained intact and no detectable cesium entered the solution. For added protection and physical strength, the coated pellets can be encased in copper and enclosed by a stainless steel canister. This apparently high level of protection is achieved, the researchers point out, at the cost of using very complex processing techniques, a problem because solidification of highly radioactive wastes must be handled entirely by remote control.

Another metal-encapsulated ceramic, called cermet, is being developed as a waste form by Scott Aaron, T. C. Quinby, and E. H. Kobish of Oak Ridge National Laboratory. The final product consists of microscopic, crystalline particles of waste oxides, aluminosilicates, and titanates dispersed in an iron-nickel alloy. Cermets are unusual because the alloy is generated from metals in the liquid waste itself and from added metals obtained from stockpiles of contaminated materials. Very preliminary leaching studies indicate that cermets are considerably more resistant at 100°C than a borosilicate waste glass.

The Swedish nuclear industry, faced with a moratorium on nuclear power development until an acceptable waste disposal plan was developed, has proposed a system of engineered barriers that depends more on sheer mass than on sophistication. Vitrified wastes would be encased in layers of stainless steel, lead, and titanium before emplacement in granite. A mixture of quartz sand and bentonite clay, a good adsorber of many wastes, would completely surround the canisters. If spent fuel rods were the final waste form, as is being considered in the United States, they would be encapsulated in lead and placed in a copper canister with 20-centimeter-thick walls.

Researchers are now testing prospective waste forms under the most extreme conditions that might prevail in a waste disposal site. In the case of glass, the objective is not to show that it is unacceptable, but rather to define conditions under which it could not be safely stored. Because the single most critical factor, temperature, can be controlled by simple dilution of wastes or cooling by delayed disposal (as planned in Sweden), there is optimism that glass can still be part of a first generation, multiple barrier disposal system. Some see the goal of studies of ceramics as the development of a second generation waste form that could be considered a dominant barrier, based on carefully controlled laboratory testing. This would, according to these researchers, relieve geologists of the burden of locating ideal sites and would present a convincing case for nuclear waste disposal to the public. Others allow that improvements may be possible in 15 to 20 years, but expect that geologic and engineered barriers will remain vital components of waste disposal systems.

—RICHARD A. KERR

Additional Readings

1. *Proceedings of the Conference on High-Level Radioactive Solid Waste Forms, 18–21 December 1978, Denver, Colorado* (U.S. Nuclear Regulatory Commission, in press); G. J. McCarthy, Ed., *Scientific Basis for Nuclear Waste Management* (Plenum, New York, in press).

THE FOLLOWING IS A SUMMARY OF A STUDY COMMISSIONED BY THE U.S. CONGRESSIONAL JOINT ECONOMIC COMMITTEE. IT IS REPRINTED FROM THE MARCH,1979 ISSUE OF THE ELEMENTS, 1747 CONNECTICUT AVENUE WASHINGTON, D. C. 20009

Jobs and Growth In the Solar Transition

Since World War II, American consumption of energy has tripled.[1] Total automotive horsepower increased sevenfold, home heating systems converted from coal to oil and then to natural gas, energy-consuming air conditioners and home appliances became commonly available, new commercial buildings incorporated artificial, energy-wasteful environments, airline travel expanded, and thousands of miles of highways were constructed. Overall energy consumption rose exponentially, climbing at a rate of 3.5 percent per year. Fossil fuels were consumed as if their supplies were limitless. Of course, they are not, and we now face the task of undoing the damage wrought in this twenty-five-year binge.

Beginning in 1970, domestic production of oil and gas began to fall. The natural limits on such non-renewable fuels began to make themselves felt. The periodic winter gas shortages, the brown-outs, and the 1973 oil crisis are all symptoms of the dilemma we face, addicted to fuels whose supply is running out. With rapidly rising prices and diminishing reserves, we have to begin a comprehensive transition in the energy we use and the way we use it.

One approach which has strong support is through the expanded use of coal and nuclear energy, including the gasification and liquefaction of coal. However, both of these energy sources impose significant external costs. The extraction of coal, whether from underground mines or from the stripmining of near-surface veins, has serious deleterious effects on land, water, and agriculture; the conversion of coal to gas and liquid fuels consumes vast amounts of increasingly-scarce water; and the burning of growing quantities of coal can have disastrous climatologic and health consequences.[2]

Likewise the increasing use of nuclear energy poses a wide variety of serious social problems. With the growth of the nuclear power industry will come a significant likelihood of a reactor meltdown, with potentially catastrophic consequences for nearby population centers. Problems of waste disposal remain unsolved. Safety and environmental pollution difficulties are serious. The danger of nuclear weapons proliferation as a result of the widespread availability of plutonium and enriched uranium are fearsome. And, finally, the security measures necessary to avoid theft and sabotage could severaly restrict our liberty.[3]

In the face of these mounting problems, an alternative must be sought. Such a policy would address the combined effects of declining supplies of oil and gas, higher fuel prices, dependence on imported oil, and worsening ecological problems in an environmentally-benign and economically-efficient manner. It would emphasize the conservation of energy and the replacement of the non-renewable fuels with renewable energy sources, primarily solar energy. These so-called "soft technologies" would adapt energy production more closely to needs of the particular end use, rather than being produced uniformly in a centralized facility.[4] They would include increased end-use efficiency, active and passive solar heating and cooling on individual building and neighborhood units, fuel production from biomass in the form of wastes, and dispersed on-site photovoltaic and wind powered electric generation.

Advocates of the coal and nuclear route, with its implication of continued energy growth, argue that this approach, in spite of its potential costs, is essential for economic growth. As one advocacy group put it, "Growth in energy use is necessary to our national prosperity and to provide the jobs that are needed today...the relationship between energy availability and jobs is direct and inevitable."[5] Clearly, many people still believe that continued growth in our consumption of energy, and especially of the non-renewable fuels--oil, gas, coal and uranium--is still essential if every American is to have a chance at the good life.

What we will show in this paper is that this view is not correct. We will demonstrate that it is possible to produce the same goods and services, and to achieve a higher GNP, by emphasizing the conservation of energy and conversion to renewable energy sources. Conservation and renewable energy can be major growth industries in the decades ahead, contributing both to the health of our economy and our citizenry. Introduction of a broad range of currently feasible conservation measures can simultaneously cut the consumption of rapidly depleting energy resources and create hundreds of thousands of new jobs. The expansion of solar energy programs can create a permanent substitute for declining reserves of non-renewable fuels and add millions of new jobs, particularly in urban areas where they are desperately needed. They can also reduce the outflow of dollars for imported oil and curb the inflationary effects of rapidly-rising fuel prices.[6]

The United States continues to experience a failure to provide enough jobs for its citizens, especially for minority groups who suffer the highest rates of unemployment. In 1978 the unemployment rate still stood at 6 percent, with black unemployment at 12% and teenage unemployment at 16 percent; "disguised unemployment" makes the real situation twice as bad. Economists do not see any prospect for an earmly improvement in this poor economic performance, and many foresee a downturn in the coming months which will make this situation even worse.

Many analysts argue that energy growth is crucial to a reduction in unemployment. In reality, the purpose of what we commonly call "energy" is to reduce the need for human labor, exacerbating the problem of providing jobs for a growing labor force. Industry has increased its output by drawing on the apparently limitless supplies of fossil fuels while shrinking its labor force. As the Congressional Office of Technology Assessment has commented, "The national energy policy of the last several decades has been to replace human labor as rapidly as possible with petroleum energy."[7] Thus the same practices which are creating the energy shortage have also been responsible for the shortage of jobs.

The ready availability of cheap energy has reduced employment opportunities in the energy-consuming industries and led to a continuing displacement of workers onto an uncertain job market. The energy industry itself cannot take up the slack; it employs a small proportion (historically, about 2 percent) of the labor force, and energy-related employment has not been growing. Both producers and the users of energy have taken advantage of the ready availability of inexpensive energy supplies to introduce highly-automated, energy-consuming production techniques, reducing employment per unit of output first in agriculture, then in manufacturing, and, most recently, in the

service sector. The economy has not grown because of rising energy consumption, but in spite of it. Total employment has increased because the total output of goods and, especially, of services has increased and overcome the "labor-saving"--that is, employment-reducing--effects of rising energy usage.

(Economists often argue that such "labor-saving" measures increase economic "efficiency" by freeing workers to perform other necessary tasks. However, when the economy is not able to provide jobs for all who need them, and when energy supplies are limited, the opposite is true. If the workers who are displaced cannot find employment, they must be supported by unemployment insurance and welfare while being economically unproductive; those who do find employment will consume additional energy in their new jobs, thus accelerating the depletion of scarce energy resources.)[8]

The nation thus faces two difficult but related problems, the continuing shortage of jobs, and the coming shortage of energy. The purpose of this paper is to show, with a specific plan, how large-scale investment in conservation and solar energy can contribute to the resolution of both problems. Most projections show only slow growth for the renewable energy technologies. However, these projections tend to be self-fulfilling prophecies. By assuming slow growth, they inhibit investment and thus ensure slow growth. We present a positive scenario that examines the implications of rapid growth, to stimulate discussions and interest in this possibility.

OVERVIEW AND CONCLUSIONS

<u>Baseline Projections: Business as Usual</u>. Conventional projections of energy consumption assume that the past relation between gross national product and energy consumption will continue into the future. More recently they have been assuming a rise in the price of the non-renewable fuels and, as a consequence, a slightly less rapid rise in demand for energy.

Until about four years ago, most projections of energy demand envisioned an aggregate demand by the year 2000 of 190 quads per year, two and one-half times our current consumption. (We use the common measure of energy output, the "quad", or one quadrillion British thermal units (Btu). A quad is approximately equal to the energy supplied by 172 million barrels of oil, 42 million tons of bituminous coal, 0.98 trillion cubic feet of natural gas, or 293 billion kilowatt-hours of electricity. In 1977 the United States consumed 75.9 quads of primary fuels.) Now, with evident signs of a decline in the rate of energy growth, projections are beginning to show more moderate increases. A "consensus" prepared by the Edison Electric Institute calls for consumption of about 150 quads in the year 2000, twice our current usage.[9] They assume continuing growth at a rate of about 3 percent per year, somewhat less than the pre-1973 growth rate of 3.5 percent, but still a continuation of exponential growth. In spite of clear signs of an approaching price and supply crunch, they continue to assume that energy consumption will grow exponentially out to the next century.[10]

The "business as usual" projections of energy consumption assume that past practices will continue into the future and that new supplies of the energy sources we use today--coal, oil, natural gas, and uranium--will be discovered as current sources are depleted. They assume that alternative sources of energy--solar heating and cooling, wind power, etc.--will play a small role during this time period and foresee an ever-growing consumption of the non-renewable energy sources. As oil and natural gas become increasingly scarce and expensive, they forecast a shift to coal and nuclear energy and, especially, to electricity produced by these fuels.

In this study we will use, as our reference base, an energy projection prepared by Data Resources, Inc., for the period 1977-79.[11] DRI assumes that oil price will rise 7.5 percent per year, to $1.31 per gallon by 1990, while natural gas prices rise 3.5 percent per year to $3.76 per thousand cubic feet. (Here, and throughout this study, we use 1978 dollars.) They then forecast a growth rate of 2.98 percent per year and total consumption of primary fuels in 1990 of 110.7 quads. Extended to the year 2000, this yields a total annual consumption at that point of 148 quads. In the DRI projection, the consumption of energy by sector and fuel type is shown in Table A-1.

Consumption of every energy source increases, but coal and nuclear power meet most of the increased demand, largely through their use in electricity production. Nevertheless, petroleum and natural gas are assumed to be still available and, indeed, are consumed in even greater quantities than today. This is possible only because of the assumption that increasing quantities of these fuels are imported (e.g., 57 percent of the petroleum is imported). However, U.S. demand will be competing with the increasing demand from other countries, including growing Third World economies, and many analysts foresee a shortfall in world supply between 1985 and 1995. For instance, the Report of the MIT Workshop on Alternative Energy Strategies concluded that, even in its moderate growth model, "energy demand growth quickly outpaces plausible projections of potential supply. It follows that historically high growth rates of energy use--rates substantially higher than ours--projected into the future are simply not realistic."[10] As noted in the introduction, this is just one of a number of potential barriers to this scenario.

Over three-fifths of all energy use takes place in the industrial and commercial sectors, where goods and services are produced and workers employed. Yet, the major consumers of energy employ relatively few people. Between 1948 and 1970, energy use by the goods-producing sectors rose 120 percent, while their employment declined 1.4 percent. By contrast, energy use in the provision of services increased 62 percent, but employment gained 75 percent.[12]

(In BLS categories, the goods-producing sectors are agriculture, forestry, fisheries, mining, construction and manufacturing; the service-producing sectors are transportation, communications, utilities, wholesale and retail trade, finance, insurance, real estate, services, and government.)

Six industries have historically consumed the lions' share of the energy used by industry. In 1968 (the year of the most recent detailed study of industrial energy use), the primary metals, chemical, food, paper stone-clay-glass products, and the petroleum and coal processing industries used 68 percent of all energy used by industry, yet employed only 25 percent of all industrial workers and just 7% of the nation's total work force.[13,1] Between 1950 and 1971, their work force increased only 2.5 percent, while their energy consumption increased 106 percent.[14]

These relationships will probably continue in a period when energy prices are rising. The response of business to rising energy prices and the prospect of shortages is difficult to forecast, since we have not encountered such a period before. Economic projections must be made on the basis of the past, but we have evidence only from a period in which energy prices were falling and supplies were plentiful.

Much will depend on the response of public policy to this new situation, as well as on the overall economic environment. Businesses may reduce output, and thus

TABLE A-1

Energy Consumption
(quad /yr.)

	Coal		Natural Gas		Petroleum		Nuclear		Hydro		Total	
	1977	1990	1977	1990	1977	1990	1977	1990	1977	1990	1977	1990
Household & Commercial	0.2	0.1	8.3	9.5	6.6	8.8					15.1	18.4
Industrial	4.2	6.1	7.2	7.9	7.3	11.3					18.7	25.3
Transportation					19.2	21.0					19.2	21.0
Electric Utilities	10.3	21.9	2.4	1.2	4.6	5.3	2.2	13.3	3.0	4.3	22.5	46.0
TOTAL	14.7	28.1	17.9	18.6	37.7	46.4	2.2	13.3	3.0	4.3	75.5	110.7

their demand for labor, in the face of higher energy prices (the "income effect"), or they may call upon more labor and capital resources to replace energy (the "substitution effect"). Studies by Jorgenson and his co-workers suggest that the substitution effect will predominate, but only slightly. Using a model driven by cost-minimizing business behavior, they find that an average increase of 54 percent in energy prices will reduce energy consumption in the year 2000 by 38 percent and raise labor demand by 1.5 percent.[14,15]

The Bureau of Labor Statistics of the U.S. Department of Labor carries on a continuing program of economic projections, in order to provide forecasts of labor demand in particular industries and occupations.[16] These projections are based upon expected levels of employment and labor productivity, with price variables playing a secondary role. Thus, though they make use of the DRI projections to ensure that their predicted level of energy production is compatible with such "mainstream" energy forecasts, they do not incorporate the effects of rising energy prices on other categories of consumption. Nevertheless, since these effects are, at this point, uncertain but likely to be small--given sufficient time for adjustment to new patterns of consumption, new transportation modes, etc.--the BLS projections seem quite usable.

The BLS forecasts that the labor force will grow, between 1977 and 1990, from 99.5 million to between 113.5 and 125.6 million.[17] This is an average growth rate of 1.4 percent, considerably slower than the 2.3 percent growth rate that characterized the 1970-77 period.

Within the BLS projections, the growing consumption of energy is not accompanied by a corresponding rise in employment in the energy industry or in the industries which use that energy. Rather, it leads to a continuing relative shift of employment away from these sectors to the more labor-intensive service sectors. Table A-2 shows the projected change in employment shares.

More than three out of every four workers entering the labor force in this period will have to find a job in the service sector where, quite frequently, wages are low and jobs provide less than full-time work. In 1976 the average wage in the service-producing sectors was $4.45 per hour, only 79% of the average wage in the goods-producing sectors.[1]

Bullard has argued that escalating energy prices will make "planned obsolescence" more expensive and will favor the manufacture of more durable products.[18] Manufactured goods will become more expensive relative to less energy-intensive services, consumers will buy them less frequently, and they will have to last longer and be maintained better. This will result in fewer assembly-line jobs and more maintenance and repair jobs.

The new jobs in the energy industry, which are of primary interest to us in this study, are largely related to the expansion of electricity production. They are jobs constructing the needed electric plants, mining and refining coal and uranium, and operating power plants. It is characteristic of these occupations that large-scale migrations of workers will be required, as fuel sources in particular locales are exploited and then depleted, and as health and safety requirements demand the remote location of power plants. These can impose severe dislocations and social costs on workers and their communities.

In general, this "business as usual" projection envisions an economic environment in which it will be difficult to achieve high levels of employment. With energy prices rising relative to other costs, increasing portions of the consumer's dollar will be taken up with direct and indirect energy costs. Until energy conservation measures can be undertaken, or alternative living modes adopted which can reduce energy consumption, relatively less income will be available for the purchase of other goods and services having a low energy, and high job, content. In this setting, conservation and renewable energy become essential parts of any strategy for full employment.

Toward Conservation and Renewable Energy. To avoid the manifold deleterious consequences of continued reliance on non-renewable fuels, we must undertake a strong program stressing conservation and renewable energy (CARE). There would be a strong emphasis on conserving energy, that is, on making the most efficient possible use of the energy we do consume, and on conversion of an increasing portion of our energy consumption from non-renewable fossil fuels and uranium to solar energy in its various direct and indirect forms (solar heating, wind, biomass). Total fuel consumption would be capped and ultimately reduced, and the mix of energy sources would be changed, with an increasing portion coming from renewable sources.

In general, energy consumption can be reduced by (i) performing the same activity in a more energy-efficient manner, (ii) using energy that is now wasted, and (iii) changing behavior to reduce the need for energy. All three should be undertaken, though the last--involving modifications in our housing patterns, our transportation systems, the way we produce goods and services--will require more time to implement and more sweeping social changes. Our present patterns have been developed in an era when energy was cheap and its supply thought to be endless. As we realize that these conditions no longer hold, we may begin

TABLE A-2

	Increase in Employment 1977-1990	Share of Total Employment (percent) 1977	1990
Goods-producing sectors	4,797,000	26.8	25.5
Energy-intensive industries	373,000	4.1	3.6
Service-producing sectors	18,352,000	71.2	72.6
Energy industry	351,000	2.0	1.9
TOTAL	23,500,000	100.0	100.0

making significant changes in the way society organizes its living and working activities.

Very large savings appear possible even without this. With relatively modest efforts in the first two categories, savings approaching one-half of current consumption can be made.[19] There are great opportunities for energy conservation, not just because we have been using energy wastefully, but also because we have been using it inappropriately. We have been using fuels and processes which produce very high temperatures (hundreds or even thousands of degrees) to heat our homes ten or twenty degrees, with excess heat simply thrown out into the atmosphere. By producing energy that is tailored to its use, and extracting all the useful work from it, we can make significant gains over our past inefficient practices. Furthermore, conservation is not expensive; estimates of the cost of conservation measures range from one-half to one-tenth the cost of adding an equivalent amount of energy from new sources.[20,21,22]

It should be emphasized that, as we (and most analysts) use the concept, "conservation" does not mean the curtailment of energy-using activities. Rather, as the CONAES Demand and Conservation Panel defined it, conservation includes "technological and procedural changes that allow us to reduce demand for energy (or specific scarce fuels) without corresponding reductions in the goods and services we enjoy."[23]

However, we will need some additions to our current supply of energy, not just conservation of what we use, and we will soon have to begin replacing fossil fuels with renewable sources of energy. We have to create an entirely new industry to produce, install, and maintain solar energy units of all kinds--hot water and air collectors and storage units, photovoltaic generators, biomass converters, wind machines, and so on. In the 1950s, a national decision created the massive federal highway system and, in the 1960s, the space program. Each involved investments of billions of dollars and hundreds of thousands of jobs. In the same way, we need to move toward a national program of solar energy production and conversion. Solar energy could be the technology that lifts the economy out of the doldrums of the 1970s into a more prosperous period in the 80s.

We will look at projections to the year 1990, assuming that such a program is initiated. The year 1990 may be looked on as a typical year in a fifty-year transition from dependence on non-renewable fuels to nearly complete reliance on renewable energy sources, primarily energy from the sun. Most homes, office buildings, and factories have useful lives of the order of fifty years. Thus, about fifty years are required to replace this building stock and convert it to energy-conserving, renewable sources.

One frequently hears expressions of concern for the employment impact of such alternative energy policies. These reflect doubts over the ability of the alternative approach to provide the energy that industry needs, in order to operate the machines on which many workers depend for their jobs. The approach adopted in this paper assumes that no policy will be adopted that does not provide sufficient energy to fuel the economy and, especially, its productive machinery. Thus the approach incorporates ways of substituting, step by step, renewable energy sources for non-renewable ones. It assumes there will be no reduction in the use of conventional energy sources, and no reduction in the supply of conventional fuels, at whatever price, until an alternative is available in sufficient quantity to meet the demand.

An extensive range of measures can be encompassed within a CARE strategy. Those postulated to be installed and operational by 1990 include the following:

(1) For residential and commercial use

--Reduction of heat loss through additional insulation, efficiency improvements in the use of heating and cooling units, and careful attention to the flow of heat in the building and through its outer "envelope".

--Improved energy efficiency of equipment and appliances.

--Increased heat absorption from the sun through passive solar designs.

--Solar water and space heating through active fluid collection and circulation.

(2) For industrial use

--More efficient industrial practices, recovery and re-use of waste heat, and use of recycled materials

--Generation of electricity as a by-product of heat and steam production ("cogeneration").

--Solar energy collectors and solar-powered heat engines.

(3) For transportation

--Increased automotive efficiency.

--Increased use of urban mass transit and interurban rail and other energy-efficient modes of transportation.

(4) For portable fuels, production of methane and alcohol from agricultural and urban wastes.

(5) For electricity production

--Photovoltaic cells, including concentrators and cogeneration, on homes, commercial and industrial buildings.

--Wind-powered electric generators.

--Solar-powered heat engine-generator systems.

TABLE A-3

Measure	Goal for Year 2000
Residential Use	
Conservation	50% saving*
Active and passive solar	100% of new homes; 50% of existing homes
Commercial Use	
Conservation	50% saving*
Active solar	50% of all buildings
Industrial Use	
Conservation	40% saving by 1990*
Cogeneration	100% of all usable sites
Active solar	25% of all process heat
Transportation	No specific goal
Portable Fuels	Conversion of 50% of waste products
Solar/Electricity	25% of current electricity production

*Energy saving goals refer to the consumption of delivered energy at the site of end use.

Other uses of solar energy, especially for cooling purposes, have not been included in the estimates made in this study because of the cost and underdeveloped nature of these systems. Similarly, capturing other forms of solar energy, such as ocean thermal energy, has been proposed, but such systems have not yet reached a sufficient stage of development to be able to estimate their energy and employment potential.

The energy savings achieved, and the number of jobs produced by these measures, depend upon the scale of investment in them. For this study we assume a set of national goals, projecting the achievement of a specified level of implementation for each measure by the turn of the century. (With different goals, the results will be scaled up or down proportionately.) The goals we assume are described in Table A-3.

These goals are ambitious but achievable with the vigorous support of public policy.

To meet them, we assume that investment in conservation and renewable energy builds up over a five-year period preceding 1985, with a constant level of investment thereafter. (Because of the need for further advances in technology, it is assumed that implementation of photovoltaics does not begin until 1985.) We find, for the year 1990, the projections shown in Table A-4.

We distinguish the "direct" jobs involved in producing and installing the final products from the "indirect" employment involved in producing raw materials and components. The jobs projected here pay wages and salaries that are typical of the respective industries in 1990, especially manufacturing and construction. One-quarter of the investment and the jobs are in energy conservation, three-quarters in solar energy. About one-third of the investment is in the residential sector; the remainder of the investment must be made by business and government decisionmakers.

For comparison, the BLS projects the gross national product in 1990 to be $3,241 billion, with gross private domestic investment equal to $510 billion. Total employment will be 114,000,000 and total unemployment 5,400,000, with the BLS assumption of an unemployment rate of 4.5%. Construction employment will be 5,574,000 and manufacturing employment 23,872,000. Thus, conservation and solar employment will impose relatively small pressure on the economy as a whole, but it can make a significant dent in unemployment.

These investments lead to very significant savings of non-renewable fuel. Rather than including solar energy in the national energy accounts as contributing positive amounts of energy, there is less ambiguity if it is viewed as a conservation measure, enabling the consumption of non-renewable fuels to be curbed. (The recently-enacted National Energy Conservation Policy Act includes solar energy and wind power devices among the energy conservation measures it promotes.) This method of accounting is especially appropriate for on-site solar techniques, where the energy supplied by solar devices is not transmitted, marketed, or even measured, but simply permits less dependence on external energy sources powered by non-renewable fuels. (Steve Baer has pointed out, for instance, that anyone who dries clothes on a clothesline will be using solar energy. As compared to the user of a gas or electric dryer, they will be using less fuel but not necessarily less energy. And the energy, of course, is not measured.)

Assuming that a strong CARE program is begun in 1980, we find that the fuel consumed in 1990, compared with the DRI business-as-usual projection, is shown in Table A-5.

TABLE A-4

	Annual Investment ($ billion, 1978 $)	Number of Jobs (thousands) Direct	Indirect	Total
Residential				
Building conservation	5.7	125	74	199
Appliance conservation	1.4	29	23	52
Passive solar	0.7	15	11	26
Active solar	14.8	266	244	510
Commercial				
Conservation	2.4	52	34	86
Active solar	6.6	119	109	228
Industrial				
Conservation	1.5	20	25	45
Cogeneration	3.8	51	62	113
Active solar	12.1	163	198	361
Transportation	--	--	--	--
Portable Fuels	4.3	89	77	166
Electricity				
Photovoltaics	3.6	69	53	122
Wind	5.3	91	81	172
Heat engines	3.4	31	59	90
TOTAL	65.6	1,120	1,050	2,170

The implementation of these CARE measures leads to a saving of 44.9 quads of non-renewable fuels. (It might be thought that we should add the fuel consumed in the course of manufacturing and installing the conservation and solar systems. However, we have no way of knowing whether this projection is part of the production already included in the BLS projection, or is an addition to it. In any case, this energy "investment" is "paid back" by these systems in a year or two and thus represents 5-10% of their useful energy delivery.[24])

Projecting forward to the year 2000, with CARE measures implemented according to Table A-4, we obtain a total fuel consumption of 52.7 quads, little more than a third of the 144 quads found if the conventional, business-as-usual path is followed. About half the savings are achieved through conservation measures, half through solar energy.

TABLE A-5

Primary Fuel Consumption (quad/yr.)

	DRI	CARE
Coal	28.1	14.2
Natural Gas	18.6	11.5
Petroleum	46.4	33.6
Nuclear	13.3	2.2
TOTAL	106.4	61.5

The conventional method of energy accounting would add to the energy sources shown in Table A-5 the contribution of hydropower and various active solar systems envisioned in this scenario. Using this approach, we find the situation as expressed in Table A-6.

Total energy consumption in the CARE scenario is just about equal to total consumption in 1977, that is, there is zero energy growth between 1977 and 1990. Solar systems provide 10.2 quads or 13% of the energy in 1990, and they provide 22 quads or 28% of the energy in 2000. (This understates the significance of solar sources; to the extent they substitute for electricity produced from non-renewable sources, 1 Btu of solar energy replaces 3.4 Btu of non-renewable fuels.) For comparison, ERDA Report No. 49, the National Solar Energy Research, Development, and Demonstration Program, projected a solar contribution of the order of 10 quads by the turn of the century; the Stanford Research Institute found 15 quads in its "solar emphasis" scenario; the Mitre Corporation projected 6 quads; the Committee on Nuclear and Alternative Energy Systems (CONAES) of the National Academy of Sciences found a high-solar scenario yielding 14 quads; and the Council on Environmental Quality projected 15-25 quads.[23,25,26,]

The savings achieved by introducing this wide range of conservation and renewable energy measures allows spending on non-renewable fuels to be reduced by $118.8 billion in 1990. We estimate that this will lead to a reduction of 644,000 jobs operating and supplying facilities that use and distribute non-renewable fuels and of 493,000 jobs in electric power plant manufacture and construction. Of the total of 1,137,000 jobs, 680,000 are directly in these industries; 457,000 are in industries that are indirectly affected by these energy savings.

By 1990, the money saved by residential, commercial, and industrial consumers from reduced fuel consumption greatly exceeds the amount invested annually in CARE

TABLE A-6

Energy Consumption (quad/yr.)

	DRI	CARE
Non-renewable fuels	106.4	61.5
Hydropower	4.3	4.3
Solar systems	--	10.2
TOTAL	110.7	76.0

measures. These extra funds can be spent to purchase additional goods and services. For the net savings of $53.2 billion ($118.8 billion less the annual CARE investment of $65.6 billion), there will be an additional 1,870,000 jobs created. The BLS projections assume that the cost of energy rises no faster than the general rate of inflation, which they project at 5.4% per year. Since the price of these fuels will very likely rise faster than this, the dollar savings will probably be greater and the number of jobs created by the shift in spending correspondingly larger. Also, to the extent that CARE investments are made out of borrowed funds rather than current income, there would be more disposable income available and, consequently, more jobs produced. On the other hand, if fuel prices are raised by their suppliers in response to the drop in demand, there would be fewer additional jobs.

Keeping in mind these caveats regarding this estimate of the jobs created (and, indeed, the approximate nature of all of the estimates in this study), we then have the net job creation in Table A-7.

TABLE A-7

	Number of Jobs Created (thousands)
Conservation	521
Solar Energy	1,649
Non-renewable fuels	- 1,137
Added disposable income	1,870
TOTAL	2,903

These figures do not include the additional jobs that would be created through the multiplier effect (spending of the income earned through this employment) and the accelerator effect (increased investment induced through anticipated growth). Such effects result from a stimulus added to an existing economic situation, whereas many of the jobs envisioned here may be part of the employment growth projected by BLS. To the extent they are not reflected in those projections, but represent additional investment beyond that in the BLS forecast, there would be a roughly-equivalent number of additional jobs created through the multiplier (re-spending) effect.

It is now widely recognized that employment programs must be "targeted" to be effective, that is, they must place funds and jobs in the regions, and among the population groups, suffering the most from unemployment. Jobs in the fuel extraction industries (coal mining, oil and gas exploration, etc.) and in power plant construction tend to be far from the areas suffering the most severe unemployment. On the other hand, energy conservation and solar energy system production and installation will take place largely in settled urban areas where the unemployment reside and where they can easily be trained and hired. Thus, the jobs created in this scenario can make a significant contribution to solving the chronic unemployment problem facing our urban areas. Some jobs, such as those involved in producing photovoltaic arrays and solar heat engines, will be in more centralized manufacturing facilities; these can replace the jobs displaced by the reduction in conventional energy investment and production.

The jobs will be dispersed as widely across the country as are the dwellings people live in and the sites of their work. It will not require workers to move to remote or temporary construction sites. Energy conserving technologies tend to be decentralized, geographically distributed in roughly the same proportion as the population. Fuel supply technologies, on the other hand, tend to be centralized and located where the fuel sources are, e.g., in Alaska, offshore, in the Rocky Mountains or the northern plains.

Jobs will be created in insulating and retrofitting homes with solar units, manufacturing and installing more efficient heating and cooling systems, making office buildings more energy efficient, producing and operating mass transit systems, producing and installing cogeneration devices, and recycling valuable materials. The skills required will be similar to those required for conventional construction projects and heating system installation. Work will be provided for sheet metal workers, carpenters, plumbers, pipefitters, construction workers, and production line workers of all kinds. Energy management will be increasingly important and will be a new source of employment for engineers and designers. Also, solar energy technology is suited to community-based enterprise and small business. Expansion of this industry will open up opportunities for ownership and economic development by those who now have little or no role in the multinational energy industries.

As energy conservation and the use of renewable energy become guideposts for community planning, land use and housing density patterns will shift. Higher densities, with a reduction of suburban sprawl, will reduce transportation energy usage and allow more energy-efficient housing construction.[28,29] Compact communities will facilitate the introduction of neighborhood-scale solar units for both heat and electricity generation.[4] Such units have a number of significant advantages, including the possibility of utilizing shared community spaces with protected access to the sun and of incorporating very large storage tanks that can store summer heat for winter usage. Very high densities (especially buildings of four or more stories) will be discouraged, since the solar resource is relatively diffuse (requiring about 400 square feet per family) and on-site energy supply would then become infeasible.

Commercial and industrial activities will require more energy planning and more land for access to the sun. (In a solarized society, land becomes an energy resource!) Though these activities may occupy a small fraction of a community's land, their solar energy needs will require several times the space they occupy.[29] There will have to be community and region-wide planning to ensure that the necessary space is available, whether on buildings or on open spaces. There may also be a tendency for energy-intensive industries to locate in areas having large amounts of annual solar radiation; though increased transportation costs may tend to counter such shifts.

In general, energy considerations will become a predominant consideration in land use planning, community organization, and the location of jobs.

Financing the Solar Transition. Achievement of the scenario envisioned in this study, and of the job creation it would generate, depends on political and economic decisions which induce the necessary investment and make available the necessary funds.

It seems likely that this will not occur unless mandatory federal standards are established governing a broad range of energy conservation and renewable energy measures (similar to the mileage requirements now imposed on automobile manufacturers). Even though price factors alone would appear to impel the introduction of these measures today, in fact, a great many of those with the ability to introduce them have not done so. The builders of homes and commercial buildings want to keep their initial selling costs down even though, over the lifetime of the building, the purchaser may well end up paying more through high energy usage for heating, cooling, and lighting. Likewise, industrial decisionmakers have been lukewarm to conservation and solar energy, insisting on twice as large a return (about 30% per year) from an investment in energy conservation as from an investment that increases productive output.[30]

Many conservation measures are relatively inexpensive and, even at today's fuel prices, would pay for themselves in energy savings in just a few months or years; as prices rise, they will become even more cost-effective. Many solar energy systems make economic sense today when compared with the cost of electricity, though not yet when compared with the cost of oil or gas.[31,32] In all cases, these financial benefits accrue in the future through some substantial investment in the present. Consumers and businesses may prefer other ways of spending their money. Generally, an energy-related investment will not markedly improve current living conditions for the individual consumer or expand sales for the businessman.

In addition, it is characteristic of most CARE measures that they are purchased by the user of energy, rather than by the current producers of energy. Whereas a power plant is purchased, constructed, and operated by an electric utility, a solar heating unit is purchased by the individual homeowner or builder for installation on the individual home. The user's return on this investment depends on the cost of the energy saved, and thus on the average cost of all facilities then producing and distributing energy. A supplier's investment choice, on the other hand, is based on the comparative cost of new facilities currently being built.

New energy production plants tend to be increasingly expensive so that, in general, an investment in conservation or solar energy would save more energy than would be produced by the same expenditure on new facilities using non-renewable fuels.[4,31] Cogeneration equipment costs industrial users more than what they are now paying for electricity, but less than what it would cost a utility to produce equivalent central power plant capacity.[33] Since the user's investment is compared with the average cost of energy, while the supplier deals with replacement cost, the user's decision is weighted against the purchase. To overcome this, some alternative financing arrangement seems to be necessary.

One is to introduce some form of national subsidy, such as the recently-approved tax credit for homeowners and businesses. However, this applies only to particular classes of taxpayers and will not address the general need for making CARE investments attractive to the energy user.

Another possibility would be to have the suppliers, especially the electric utilities, purchase (or loan the money for) conservation and solar installations. These investments would then be incorporated into the internal accounting of the energy producers. However, this would negate some of the main advantages of renewable energy systems, namely, their flexibility and amenability to control by the user. It would seem preferable to set up an alternative financing scheme which would accomplish the same end, that is, introducing a broad societal perspective into the financial arrangement, without transferring control to the current suppliers of energy. Since suppliers' investments will, in any case, be based on borrowed money which is repaid through payments by consumers, it should be possible, in principle, to devise mechanisms which would achieve this.

One would be an energy development bank which could borrow large sums at attractive rates on the private money market and loan these for CARE purchases, either directly or through local banking institutions, to sers (including communities for shared, neighborhood-scale facilities). In effect, this federally-backed bank would be borrowing the sums that would otherwise be drawn on by the utilities and other energy suppliers, and making them available to energy users. By loaning them out for long terms at low interest, the monthly cost to users can be reduced below what their energy spending would otherwise be. (Indeed, the San Diego Savings and Loan Association is already making available loans which are extensions of a homeowner's mortgage, so the homeowner may end up with no additional monthly cost for the CARE installation.)

With the introduction of a financing mechanism such as this, with a broad-based educational effort, and with the strong support of public officials, it should be possible to launch a national conservation and renewable energy program that would have the very great employment benefits identified in this study.

--Leonard S. Rodberg

(This article is excerpted from "Employment Impact of the Solar Transition," November, 1978, and originally prepared by Leonard S. Rodberg of the Public Resource Center for the Subcommittee on Energy, Joint Economic Committee, U.S. Congress. The subcommittee shortly will publish the full paper.)

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March 1977-March 1979	Director of L.I. Jobs Study: Council on Economic Priorities, New York, N.Y.
1975-February 1977	Branch Chief, Program Manager: Division of Solar Energy. Environmental Scientist: Office of NEPA Coordination, Energy Research & Development Adm., Washington, D.C.
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EDUCATION

M. A., Urban Affairs, 1975, Virginia Polytech Institute (pending).

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Fellow, Scientists Institute for Public Information, 1977.

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Past 9½ years - Physicist with Colorado Department of Health, Denver

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A.P. Sloan Foundation Research Fellowship (1974-8);

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MEMBERSHIP

American Physical Society (service on Committee on Problems of Physics and Society, 1970-1; Forum on Physics and Society Organizing Committee, 1971; APS Nominating Committee, 1971-2; Committee on the Future of the APS., 1972; ad hoc APS-AIP Committee, 1972-3; AIP Committee on Physics and National Problems, 1973-4; APS Committee on Summer Studies in Energy, 1973; Forum on Physics and Society Executive Committee, 1974-)

American Association for the Advancement of Science (service on AAAS Youth Council, 1972; worked with W. Golden and others to create the AAAS-APS Congressional Science Fellowship programs, 1972-3; AAAS Committee on Scientific Freedom and Responsibility, 1976-)

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Co-organizer of Stanford Workshops on Political and Social Issues, 1969-70; member, McGovern Panel on National Security, 1972; consultant to Ford Foundation Energy Policy Project, 1973-4; consultant to NSF Subcommittee, U.S. Senate, in developing Science for Citizens program, 1974-6; consultant to California Energy Resources Conservation and Development Commission, 1976- ; member, Science Court Task Force, Presidential Advisory Group

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Joel Primack, "Better Alternatives to Plutonium Recycling and the Fast Breeder Reactor: An evolutionary Strategy for Nuclear Power Development with Uranium Stockpiling," Proceedings of the 28th Pugwash Conference (Varna, Bulgaria, September 1978).

VITA

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PRESENT ADDRESS

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POSITIONS HELD

Instructor, Women and the Law, University of Michigan, Ann Arbor, 1973.

Visiting Lecturer, National University of Mexico, Mexico City, 1974.

Judicial Clerkship, New Jersey Superior Court, 1973-74.

Research Associate, International Juridical Organization, Rome, Italy, 1974-75 (International Environmental Law).

Consultant to Ford Foundation, Government and Law Section, on alternative dispute-resolution systems, 1975-76.

Professional Staff, R&D Policies and Priorities Program, Office of Technology Assessment, U.S. Congress, Washington, D.C., 1976-77.

Lecturer, Science and Law, University of California, Santa Cruz, 1977.

Consultant to Swedish Energy Commission, Stockholm, 1978.

EDUCATION

B.A. (General Honors) University of Chicago, 1969, in History and Philosophy of Science.

Diploma, Mexican Law, Escuela Libre de Derecho, Mexico City, 1972.

J.D. (cum laude) University of Michigan, 1973.

HONORS

Woodrow Wilson Designate, 1969.

Fulbright Scholar, 1974-75 (Italy).

PROFESSIONAL MEMBERSHIPS

Member of the Bar of the State of New Jersey

American Bar Association

American Association for the Advancement of Science

PUBLICATIONS

"The Environmental Problem of the Oceans: an International Stepchild of National Egotism," 5 Environmental Affairs 3, Winter, 1976.

"Mediation: a Better Alternative to the Science Court," Bulletin of the Atomic Scientists, April, 1977, p. 50 (co-authored with R. Stephen Berry).

Disposal of High Active Nuclear Fuel Waste: A critical review of the Nuclear Fuel Safety (KBS) project on final disposal of vitrified high active nuclear fuel waste, Energy Commission, Department of Industry, Government of Sweden, Stockholm, 1978. Co-author (with Thomas B. Johansson) of Chapter 1 on procedure; author of Appendix IIA on legal aspects.

INVITED PARTICIPATION AT CONFERENCES

Vienna Conference on East-West Cooperation, Vienna, Austria, Nov. 1974. Paper presented: "European Cooperation on Laws for International Environmental Protection."

Bled Conference on the Environment, Bled, Yugoslavia, June, 1975. Paper presented: "Ocean Pollution and International Law."

Science Court Colloquium, Virginia, 1976.

Ethics and Values in Science and Technology, NSF planning conference, Reston, Virginia, Dec. 1976.

National Academy of Sciences Forum on Recombinant DNA Research, Washington, D.C., March, 1977.

Critical Experts Conference on Nuclear Waste Management, Stockholm, Sweden, Paper presented: "Serious Inadequacies in the Swedish-French Contracts for Reprocessing Spent Fuel."

American Bar Association Annual Meeting, New York City, August, 1978. Paper presented (before the ABA Science and Technology Section's Symposium on Conflict Resolution in Technological Issues): "A Swedish Experiment in the Nuclear Waste Controversy."

Keystone Conference on Nuclear Waste Management, Keystone, Colorado, Dec. 1978.

Neighbor States Experience Nuclear Pluses, Minuses

By the Associated Press

Nuclear generating plants are under construction in Missouri and Kansas, but neither state has any that are producing power. Several neighboring states do have such plants in operation, however, and The Associated Press searched Nuclear Regulatory Commission records and came up with status reports on those plants.

Iowa

DUANE ARNOLD—This plant has had its troubles. It is owned by Iowa Electric Light and Power Co. and Central Iowa Power Cooperative and is located near Cedar Rapids.

Since it began operation in 1975, it has generated only 49.3 percent of its realizable electrical power. The 538-megawatt reactor had a particularly bad year in 1978, when it generated only 27.2 percent of its capability and ranked next to last among operating plants.

When the plant was closed for an unrelated problem in June, a crack was found in one of the 10-inch pipes that feeds vital cooling water to the reactor. One note in NRC documents said the crack was "spraying water." The shutdown continued through the rest of the year and into this year as cracks were found in other pipes.

In 1976 the plant was rated "C"—below average—for the year's safety operation.

In 1976 it had the second-highest number of reported incidents and the second-highest number of reactor coolant problems.

Nebraska

COOPER—In January 1976 there was an explosion of hydrogen gas at the Cooper Station plant, 23 miles south of Nebraska City. The blast occurred in an auxilary building and not in the reactor.

This explosion of gas thrown off by the reactor was handled by the equipment designed for it. But there have been similar blasts at other plants that have caused damage, and the NRC says it is worried about the explosions.

This 778-megawatt plant, owned by Nebraska Public Power District, produced 73 percent of its possible output in 1978, ranking 28th. Since it began operation in 1974, it has produced 62.4 percent of its capacity, placing it 36th among all plants.

FORT CALHOUN—On September 8, 1978, a puff of radioactive gas was accidentally released at the Fort Calhoun nuclear plant, 19 miles north of Omaha.

This "inadvertent radioactive gas release"—as NRC documents describe it—is an incident that isn't supposed to occur but does. There have been "unplanned releases" at many other plants, in addition to Fort Calhoun.

This 457-megawatt plant, fired up in 1973 by the Omaha Public Power District, has had other problems. In 1976 production was limited because some of the sensors in the reactor core suffered numerous failures. In June 1978 it was down for 10 days to repair reactor-coolant pump seals.

Last year Fort Calhoun ranked 32nd in production performance, putting out 71.2 percent of capacity. Since it began work, the production has been 62.8 percent of the maximum.

Colorado

FORT ST. VRAIN—The plant at Fort St. Vrain, north of Denver, is the only high-temperature gas-cooled power reactor in the country. The 330-megawatt unit still is undergoing tests and has not begun full-scale power production for Public Service Company of Colorado. In January 1978 radioactive helium escaped from a ruptured cooling pipe, and 15 plant workers were contaminated.

Illinois

DRESDEN 1, 2 and 3—These three plants, near Morris, are part of Commonwealth Edison's large commitment to nuclear power. The utility owns five nuclear plants and is part-owner of two others.

NRC's study of 1976 operations gave Dresden a "C" rating, meaning it was below average in complying with safety rules.

An NRC inspector said the utility had management problems "associated with 'bigness.' " This NRC inspectors also judged that the overall attitude toward safety by plant personnel was "worse" because of operational and instrument problems.

Recent NRC inspections of the Dresden units found entrances to some high radiation areas that were neither locked nor equipped with alarm or other control devices.

Dresden 1, which went into operation in 1960, is the smallest plant at the site—having only a 207-megawatt capacity. In 1978 the plant produced at only 44 percent capacity, partly because of scheduled shutdowns for cleaning and refueling.

Dresden 2, which went into operation in 1972 with a capacity of 794 megawatts, produced at 84.4 percent capacity in 1978, one of the best records in the industry. The unit recently had a number of minor problems with valves and pumps and was shut down briefly twice in February because of equipment problems.

Dresden 3, a 794-megawatt reactor that became operational in 1971, had a series of problems last year and produced at only 56.6 percent capacity. The unit was shut down at the beginning of the year to replace its main transformer, which caught fire in February and triggered an emergency reactor shutdown.

QUAD CITIES 1 and 2—These two 789-megawatt plants, 20 miles northeast of Moline, have mediocre power production ratings, placing 33rd and 40th overall, but have been improving in recent years.

Quad Cities 1 had a performace figure of 70.1 percent in 1978, up from 64.9 percent in 1977 and 63.7 percent in 1976. Unit 2 reached 65.7 percent last year, up from 52.3 percent in 1977 and 50.2 percent in 1976.

NRC documents indicate two reasons for part of the low ratings: low demand from Commonwealth Edison—the owner of both plants—for power, and a cooling-water agreement with the state that lowers efficiency.

In March 1974 Unit 1 had an explosion in one of the off-gas lines, which carry radioactive hydrogen gas away from the reactor. Although the equipment is built to withstand such a blast, the NRC is worried about hydrogen explosions.

ZION 1 and 2—On three days in 1977, these two 1,040-megawatt Commonwealth Edison Co. plants had serious problems because its operators made mistake after mistake.

On July 8, the operators omitted some steps in a procedure and shut off an emergency shutdown device before it had finished. On July 10 and July 12, personnel made mistakes that could have, but didn't, trigger major problems.

In 1976 NRC gave the Zion plants a "C" rating, meaning they were below average in complying with safety rules.

Zion 1 went into operation in 1973, and Zion 2 went on line in 1974. The plants, about 40 miles north of Chicago, produced at about three-quarters capacity in 1978.

The 1977 NRC survey of agency inspectors showed that the Zion plants found one inspector saying that "overall attitude regarding safety is not strong. Lax operating performance and attitude."

Wisconsin

LACROSSE—This small (50 megawatt) reactor has had big problems. In May 1977 part of its radioactive fuel

willing to live within sight of a nuclear power plant, compared with 45 percent who said "Yes" to the same question in 1977. This year, 60 percent of those surveyed wouldn't live that close to nuclear power, compared with 47 percent in 1977.

Of those who said "No," 85 percent listed fear of radiation as the main reason, compared with 70 percent in 1977.

The reason cited most often in both Callaway and Coffey counties for supporting the plants—76 percent of those in Fulton favoring the Callaway plant and 55 percent of those in Burlington favoring Wolf Creek—was the need for more electricity.

Half those favoring the Wolf Creek plant cited its "proven safety" and the prospect for "clean, safe energy" as another reason for their support, compared with 18 percent of those favoring the Callaway plant.

"That is our only alternative," said an older Burlington woman. "Our coal is running short. Wind power did not prove successful in early years. All our natural resources are being depleted."

In Burlington, 30 percent of those favoring Wolf Creek cited its economic benefits for their area, compared with 18 percent of those favoring the Callaway plant.

That may be a big reason for the different survey results in the two communities. Burlington, a town of about 2,500, has one-fifth the population of Fulton, and Coffey Countians feel more direct benefits from Wolf Creek.

Burlington was in economic trouble before the plant work began, something still reflected in the survey. Sixty percent of those questioned in Coffey County have family incomes of less than $15,000 a year, compared with 40 percent in both Fulton and Greater Kansas City.

"It will do good things for this area—it is depressed," said a longtime Burlington resident.

Fear was cited by 65 percent of those opposing the Callaway plant and 28 percent of those opposing Wolf Creek.

A young mother in the Burlington area explained that she's just two miles from the plant and "I have a 3-year-old child. If anything happened here, we would have to pack up and evacuate."

A young Fulton woman said, "I don't know about it, and what I know frightens me. For example, where are we going to put the waste?"

Few Burlington residents mentioned radioactive waste disposal, but that was a major issue to 16 percent of those who opposed the Callaway County plant.

Eleven percent of those opposed to Wolf Creek complained about the damage to area farmland, but a longtime resident noted, "I was the third guy to sell out to them, and I'm happy and proud I did. It is needed and should have been done a long time ago."

A young Fulton man said, "People were pushed off their land . . . Callaway County is not ready for a nuclear plant."

A plant worker in Burlington snapped, "The people doing the hollering are the ones too ignorant to educate themselves."

But a second worker said he "wouldn't build one (a nuclear plant) ~~where I was going to~~ live . . . By the time they build one, it's out of date."

Another worker countered, "I'm going to live here when it's done."

A young woman was blunt: "Mainly, it keeps me alive. My husband works there."

(The survey identified those persons whose families include a plant employee. Thirty-one percent of those contacted in Burlington were involved in the plant, compared with 18 percent in Fulton—not enough to explain the broad support for the Wolf Creek plant. Of those, 9 percent in Burlington opposed the plant, and 35 percent of those in Fulton opposed that plant. Market researchers warn that it isn't possible to draw definite statistical conclusions from that small part of the total survey.)

Many comments showed lukewarm support for both plants.

A middle-aged Fulton woman, who opposes nuclear power but supports the Callaway plant, explained, "I guess there's not much I can do about

Kansans, Missourians Differ

KC Area Residents Do Nuclear About-Face

By John M. Wylie II
Star Energy/Environment Writer

Kansas Citians, who strongly favored nuclear power in 1977, have turned against it in the wake of last month's crisis at the Three Mile Island nuclear plant in Pennsylvania, according to a telephone survey by *The Star*.

In contrast, neighbors of Kansas' first nuclear power plant support it by a 3-1 margin, but those living near Missouri's first nuclear power plant oppose its construction, separate surveys by *The Star* show.

In the survey of 324 Kansas City area residents conducted last week by *The Star's* Market Research Department, 44 percent said they opposed construction of nuclear power plants, 42 percent said they supported such construction and 14 percent were undecided. When the same question was asked in September 1977, 55 percent favored construction of nuclear plants, 29 percent were opposed and 14 percent hadn't decided.

In Coffey County, Kan., a survey of 102 residents showed 60 percent in favor of nuclear power in general and 65 percent in favor of the Wolf Creek nuclear plant under construction in Burlington. Twenty percent opposed the Wolf Creek plant, and 22 percent opposed nuclear power in general. The others were undecided.

One Burlington resident called the plant "great—best thing ever!"

U.S. Rep. Albert Gore of Tennessee has been hearing an earfull of doubts about nuclear energy from his constituents. Page 13A

In Missouri, the Pennsylvania nuclear crisis also is causing some second thoughts. Page 27A

But in the Fulton, Mo., area, the population center of Callaway County, 54 percent of the 95 persons interviewed opposed nuclear power in general and 46 percent opposed the Callaway County nuclear plant, which is under construction. Forty percent supported the local plant, and 39 percent supported nuclear power in general.

The Wolf Creek plant—a joint project of Kansas City Power & Light Co. and Kansas Gas and Electric Co. of Wichita—and the Callaway plant, being built by Union Electric Co. of St. Louis—are scheduled to begin operating in 1983. A second nuclear plant is scheduled at the Callaway site in 1987.

The Three Mile Island plant accident was a big factor in crystalizing views. In the Kansas City survey, 48 percent of those polled said it had affected their opinions. Of those, 23 percent favor nuclear power, 71 percent oppose it and the rest are uncertain. One-third of those who oppose the Callaway plant cited the Pennsylvania accident as the main reason, and 14 percent of those against the plant in Burlington mentioned Three Mile Island.

"I think they're hiding a lot of danger from the public," said a Kansas City man.

"Just the fact that they don't know enough about them (nuclear plants), that's enough for me. I don't think I was convinced until then. Now I am," said a Johnson County salesman.

A middle-aged man living 12 miles from the Callaway County plant site said, "It took the little town there in Pennsylvania (Middletown) and tore it up. You never know when radiation is going to get out."

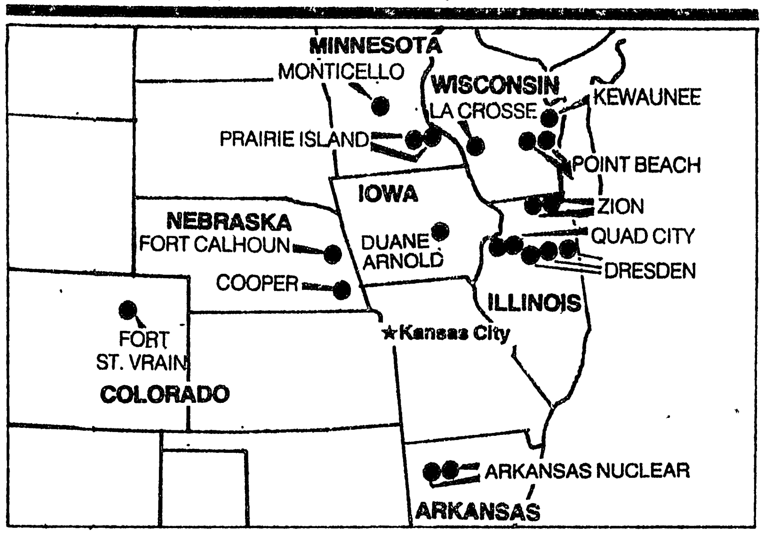
Others saw a different meaning in the accident. "The Three Mile Island thing proves it can be contained," said the wife of a Wolf Creek plant worker.

And a Johnson County woman said, "This is a bad time to answer that question. It's a thing that's going to be here. We're going to have to learn to live with it."

The Johnson County woman was among 35 percent of the Greater Kansas Citians surveyed who would be

See POLL
Page 15A, Column 1

NUCLEAR POWER PLANTS



Holmes Knaus/staff

disintegrated, and some of the fuel assemblies disappeared in the worst incident of fuel damage ever seen in a boiling-water nuclear plant.

The LaCrosse plant, owned by the Dairyland Power Cooperative, has been a poor performer. In 1978 it pumped out 41.4 percent of its realizable power, putting it 58th among all plants.

Overall, the plant has produce 47.3 percent of its rated capacity, putting it 59th among all plants.

KEWAUNEE—The 535-megawatt Kewaunee plant, 27 miles east of Green Bay, has attained a 75.7 percent production performance since it was started up in 1974. Last year was better than average, with 85.5 percent of maximum realizable power.

The plant, owned by Wisconsin Electric Power Co., has been fairly consistent. In 1976 it had one uninterrupted 61-day run and one straight 85-day run. In the last seven months of that year it ran at the equivalent for full output for 19 days out of 20—a performance the NRC called "impressive."

POINT BEACH 1 and 2—For most of last year, these two 497-megawatt reactors purred along without trouble. Point Beach 2 ran for 233 straight days without a shutdown, ending Dec. 9, when it was taken down for repairs.

Unit 1 was down for refueling in September and October, but technicians managed the task in just 22 days.

Both Point Beach reactors, operated by Wisconsin Public Service Corp., managed production levels of about 90 percent. That record was topped or equaled by only two other reactors in the country.

Unit 1 went through 1976 with only four hours of unscheduled downtime.

Even here, the operator has reported on occassional problem. For example, in January a "valve (was) not completely latched" on Point Beach 1. A failure of a valve to shut was one of the many factors that led to the near-disaster at Three Mile Island.

The plant, located 15 miles from Manitowoc, is owned by Wisconsin Public Service and Wisconsin Power and Light Co.

Minnesota

MONTICELLO—This 545-megawatt plant pumps out electricity from a site 30 miles northwest of Minneapolis. The Northern States Power facility has been a fairly consistent performer since it went on line in 1971.

The reactor produced 82.1 percent of its rated capacity in 1978, tying for ninth among all reactors in production rating. Since its startup, the plant has produced 71.9 percent of capacity, ranking it 15th among all plants.

PRAIRIE ISLAND 1 and 2—These 530-megawatt reactors 28 miles south of Minneapolis have been operating without major problems since they were put into production in 1973 and 1974.

The Northern States Power facilities were third and fifth in power production in 1978, with Prairie Island 1 generating 85.8 percent and Prairie Island 2 putting out 88.4 percent.

Overall, Prairie Island 1 has been generating 72.1 percent of capacity and Prairie Island 2, 77.8 percent. That puts them 14th and 10th, respectively, among operating plants.

Arkansas

ARKANSAS NUCLEAR ONE-1—This 850-megawatt plant, six miles northwest of Russellville, began commercial production Dec. 19, 1974, and is operated by Arkansas Power & Light Co. It also is near average in power production, ranking 30th in the nation for producing 64 percent of its rated capacity since opening.

In 1976 it had the third-highest level of reported reactor coolant problems among plants of its type but dropped to eighth in such problems the following year.

ARKANSAS NUCLEAR ONE-2—Arkansas Power & Light Co. will begin commercial operation this year of a 912-megawatt plant on the same site. In a 1977 report, an NRC inspector noted the same management would run both units. "I feel this practice considerably dilutes management control over these plants," the inspector said.

it. We are going to have to have some source of energy."

A woman in Burlington said, "It would be a big waste if they stopped it now. It's already ruined the farmlands, and the money poured into it would be lost."

Support for other energy sources has dropped a bit. For example, use of solar energy and wind power, which garnered 82 percent support in 1977, received a 76 percent favorable rating this year in the Kansas City survey. Opposition to solar energy and wind power almost doubled, from 7 percent to 13 percent.

Support for coal power plants was down 9 percent from 1977, though it still received a 71-12 percent vote of confidence.

The sex of respondents was a major factor in opinions about nuclear power. In Greater Kansas City, 54 percent of the men contacted favored nuclear plant construction compared to 29 percent of the women.

Age also played a role. In the Kansas City survey, only those in the 35-49 age bracket supported nuclear power (50-39 percent with 11 percent undecided). Those 50 or older said "No" to nuclear power 44-36 percent, and the 18-34 age group opposed nuclear plants 48-43 percent.

The survey showed no age group in Kansas City would be willing to live near a nuclear plant.

Karl Seyfrit, regional director of the federal Nuclear Regulatory Commission in Arlington, Texas, said attitudes may change again after the Three Mile Island accident fades further into history.

"I think a lot of it is probably a reaction that may turn around after all the facts are out and the event is better understood by everybody. I don't know, I'm not a seer," he said.

Many observers have suggested that the popular movie "The China Syndrome" has played a major role in shaping public opinion about nuclear power. It depicts a fictional nuclear power plant accident, similar to parts of the Three Mile Island crisis. But only two of the 521 persons surveyed in the three polls mentioned the movie, though many mentioned newspaper articles or news broadcasts.

Bob Rives, vice president of Kansas Gas & Electric, said he couldn't explain why his company's nuclear plant had strong favor from area residents while its Missouri counterpart faced substantial opposition. He said he wasn't surprised by the Kansas City survey results.

"We are just pleased to see this level of support continue," he said, noting that support was higher than in a company-sponsored survey in October.

Survey Method

The Star's examination of public opinion about nuclear power involved three separate telephone surveys by the newspaper's Market Research Department.

The survey of Kansas City area residents involved a random digit dialing technique that assures a representative number of persons in each of the metropolitan area's telephone exchanges is interviewed. A total of 324 interviews were completed between April 13 and last Wednesday, excluding the Easter Sunday holiday. Interviewers are trained, independent professionals.

In Coffey County, Kan., and Callaway County, Mo., interviewers selected numbers at random from the most recently published telephone directories from Burlington, Kan., and Fulton, Mo. A total of 102 interviews were completed in Kansas; 95 were completed in Missouri last Monday through Wednesday.

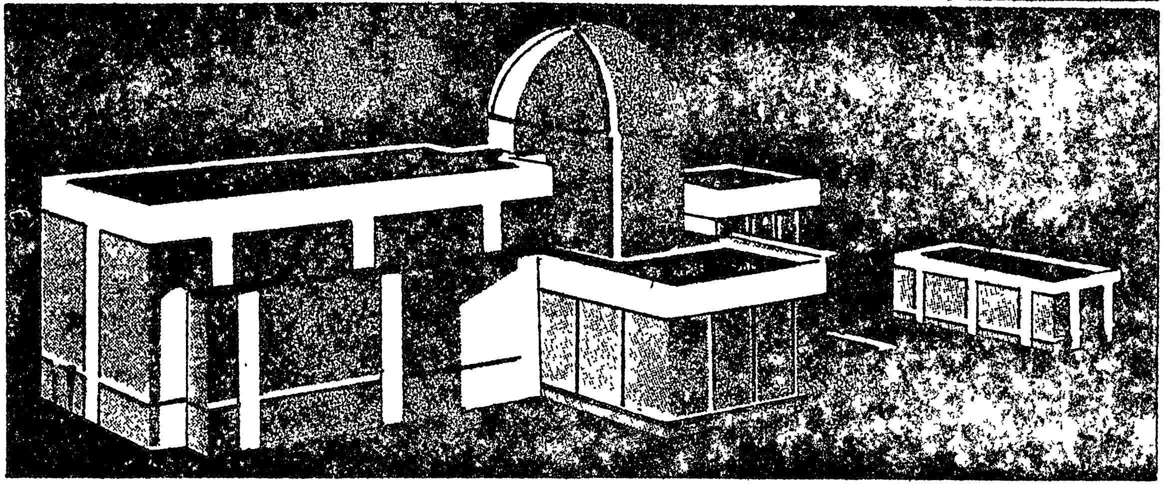
All those interviewed were assured that their identities would remain confidential.

Various methods were used to ensure the accuracy of the survey. Using standard tests, the survey is considered accurate within 6 percent.

This is the fourth energy survey conducted in the Kansas City area by *The Star* since 1973, but it is the first survey of the Fulton and Burlington areas.

Survey questions were developed by John M. Wylie II, *The Star's* energy/environment writer, and by Ms. Jackie Nixon and Mark Smith of the Market Research Department.

AREA OPINIONS ON NUCLEAR POWER



COFFEY COUNTY, KAN

	NUCLEAR POWER IN GENERAL	WOLF CREEK NUCLEAR PLANT
FAVOR	60%	65%
OPPOSE	22%	20%
DON'T KNOW	18%	15%
REFUSED	---	---

SOURCE: KANSAS CITY STAR MARKET RESEARCH DEPT

CALLAWAY COUNTY, MO

NUCLEAR POWER GENERAL	CALLAWAY COUNTY IN GENERAL
39%	40%
54%	46%
7%	12%
---	2%

KANSAS CITY METRO

	APRIL 79	AUGUST 77
FAVOR NUCLEAR PLANT CONSTRUCTION	42%	55%
OPPOSE NUCLEAR PLANT CONSTRUCTION	44%	29%
DON'T KNOW	14%	14%
REFUSED COMMENT	0	2%

Holmes Knaus/staff

St. Louis Globe-Democrat Wed. Apr. 25,1979

Union Electric shareholders blast energy industry critics

By DAVID M. GREBLER
Globe-Democrat Business Writer

UE stockholders attending the company's annual meeting at the A.J. Cervantes Convention Center here Tuesday joined their outspoken president, Charles J. Dougherty, in calling for more realistic appraisal of energy needs and financial aspects of the industry. They endorsed the committment to nuclear power and joined Dougherty in criticizing the Missouri Public Service Commission (PSC) which regulates the St. Louis-based utility's rate structure, as well as other government regulation of utilities and nuclear energy development.

"I have a lot of love for our lady friend in Jefferson City," Carl Craig, a shareholder from Godfrey, Ill. quipped sarcastically, in reference to PSC Commissioner Alberta Slavin, a consumer advocate who has often been at odds with UE.

"Speak for yourself," Dougherty interjected.

"I would like to extend my hand," Craig continued, "down her throat and turn her inside-out. Maybe then she could learn there are two sides to an issue."

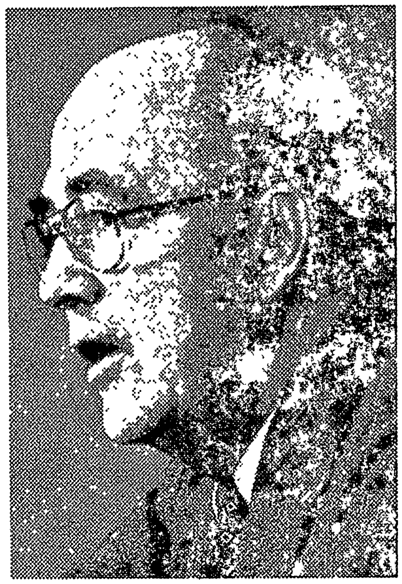
IN THE MIDDLE OF THE applause which greeted Craig's comments, Dougherty assured the some 800 shareholders present that "Mr. Craig was not a plant."

Craig complained that he started buying UE stock in 1966, when it traded at about \$27.50 per share; today it is trading under \$14 per share.

Although UE's dividend payout has increased 28 percent since Craig started investing in the company, he said he has lost a third of his capital and makes a return of only about 7½ percent.

In view of last month's accident at the Three Mile Island nuclear power plant near Harrisburg, Pa., a number of shareholders were concerned about UE's liability in case of an accident at its plant under construction in Callaway County.

UE IS ADEQUATELY INSURED IN case of any problem, Dougherty explained. Harsh federal legislation, he said, makes companies "strictly liable, which means no-fault liability. In return



Charles J. Dougherty

for that strict approach, it sets a limit of \$500 million."

UE is insured for about \$160 million at Callaway, Dougherty said. Another \$360 million coverage would be provided by a cooperative fund established by the 72 nuclear units in operation in this country.

"On a very conservative basis, the estimate is that in the first year of operation, Callaway Unit No. 1 will save \$58 million," Dougherty said.

If the PSC passes that savings through to customers, "as we suspect it will," then consumers should pay for the plant, he added. If stockholders underwrite the financial risk of building the plant, then they should get the benefits.

"YOU CAN'T HAVE A SYSTEM where you get all the benefits and I take all the risks," he said.

Shareholder Charles Rakers joined those supporting the need for nuclear power plants, citing "a few pluses of the Callaway plant."

"First, it will relieve the onerous burden in meeting air emission standards," he noted. "Second, it will cut down on the use of precious natural gas. The opponents of nuclear power should bear these facts in mind."

These comments were again greeted by enthusiastic applause. Dougherty noted that, in addition to being a stockholder, Rakers is a "union employee of the company, who took vacation this week to come to this meeting."

UE's first quarter net earnings totaled \$29,581,000, compared to \$22,158,000 for the same period of 1978. Common stock earnings totaled \$23,821,000, or 46 cents per common share, up from \$16,398,000, or 35 cents per share a year ago. Revenues reached \$240,256,000 compared to \$212,637,000 a year ago.

A common stock dividend of 36 cents per share was declared on UE's common stock, payable June 29 to shareholders of record June 8, 1979. Preferred stock dividends, payable August 15 to shareholders of record June 20, 1979, were also announced.

GROWTH IN DEMAND FOR electricity, and UE's plans to fulfill that demand, will continue strong, he added. During the next five years, kilowatt-hour sales are expected to increase at an annual rate of 3½ percent, or about 20 percent for the period.

By the end of 1983, UE should have more than 1 million customers, 61,000 more than today. To meet this demand, UE is "engaged in the greatest expansion program in our history." At the end of 1978, the company's investment in property totaled \$3¼ billion. Construction costs are estimated at \$415 million for 1979, and \$2¼ billion over the five years ending in 1983.

Other comments and stockholder questions centered on concern over nuclear energy, which was heightened by the incident at the Three Mile Island nuclear plant in Pennsylvania last month.

Dougherty stressed that, while a 'melt-down' of that reactor was possible, "as horrible as that result would have been, it would not have even approached the magnitude of the major catastrophe billed by the media."

In that incident, he added, "the safety systems worked. Despite mechanical failure and human error, the system delivered safety to the public. The nuclear power industry's record for public safety is still clean."

Pro-Nuclear Forces Grasping at Straws

tom wicker

NEW YORK — It will not surprise those who have raised questions in the past about the risks of nuclear power plants that the industry and its apologists have opened a counterattack following the near-catastrophe at Three Mile Island. Theirs may be the most defensive special interest this side of the gun lobby.

Now, people finally made aware by the Pennsylvania accident of the dangers of nuclear power are being told, in speeches, some government statements, friendly newspaper editorials and published letters to editors, that:

The real reason the public is so upset is because of what one correspondent tells me was "hysterical and sensation-seeking" coverage by the news media from Three Mile Island.

But no catastrophe actually happened — no one died, the bubble didn't burst. In fact, the systems and technicians worked, and we should be proud of them.

Anyway, the risks associated with nuclear power are normal and minimal, less than those of many other industries or in the use of coal and oil. One letter-writer to *The New York Times* complained, for example, that after a jetliner went out of control over Detroit and nearly crashed with 87 on board "there were no big headlines, no editorials, no public demonstrations and no political demagogy," as he said there had been after Three Mile Island.

The public and the press and the government should now get out of the way and let the engineers get back to the job of solving the energy crisis through nuclear power.

This latter claim has had unwarranted support from the top — implicit, at least, even in President Carter's appointment of a special commission to find out what went wrong and fix it so it won't happen again. Both Carter and Energy Secretary James Schlesinger, moreover, have renewed their calls for speedier licensing of nuclear plants.

But not only is the public clearly in no mood to countenance plants like the one at Three Mile Island being put into operation more speedily and with fewer regulatory requirements; the claims of urgent need being made for such shortcutting can't really be sustained.

Nuclear plants produce nothing but electricity. Dr. Vince Taylor, an energy consultant, has pointed out the electricity accounts for only about a tenth of "end-use energy" — that consumed by final users of various forms of energy. Therefore, replacing all oil and gas now used for electricity production with nuclear power would reduce oil consumption by only about 12 percent — and, at that, provide electricity far more costly than that produced by burning oil. Taylor estimates that these considerations will limit nuclear power to "about 10 percent of supply in the year 2000" and stave off critical oil shortages by less than five years.

So turning loose the engineers to give us more and even safer versions of Three Mile Island will not solve the energy crisis but, at best, make a useful contribution to that end. And the sooner the United States begins to pour into other energy sources most of the vast sums it has been earmarking for nuclear power, the sooner the nation can cope with that crisis.

The linked debaters' points that no catastrophe actually occurred and that the risks of nuclear plants are less than those of commercial flight, or from air pollution caused by coal make a puerile argument. It was the unmatched *potential* of the accident at Three Mile Island, for future as well as current generations, that set it apart from any other form of hazard.

That this particular accident was contained was merely fortunate — the only word, in view of the fact that published transcripts of Nuclear Regulatory Commission discussions during the event show that even the best authorities were not sure what was happening, had not expected much of what did happen, disagreed among themselves on what to do about it and had trouble getting from the plant operators the necessary information on which to make rational judgments about protecting the public.

The effort to shift the burden of guilt to the press is as familiar as Spiro Agnew used to be. Granted that newspapers and broadcasters have many sins to answer for; granted, too, that the press does not have its own authorities on nuclear physics, or many reporters with a solid knowledge of that field.

Here again it was the *potential* of the thing that demanded coverage as urgent and extensive as a press so limited could provide. And here again it was the confusion and obfuscation and misleading statements of officials presumed to be knowledgeable and responsible that were principally responsible for confused and occasionally overwrought reports. And it ill becomes those whose failures and errors threatened such catastrophe to point a finger at reporters whose duty it was to inform the public as best they could.